

Article

Coding Decoded: Exploring Course Achievement and Gender Disparities in an Online Flipped Classroom Programming Course

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Abstract: In introductory programming courses (IPCs), students encounter various difficulties that are related to low achievement and high dropout and failure rates. Technology-rich approaches that promote self-directed learning while facilitating competency development and knowledge construction through social collaboration may offer advantages in this context. The current study assesses such an instructional approach by (1) identifying antecedents and process variables related to course achievement in an online flipped classroom IPC and (2) testing for gender differences regarding antecedents, process variables, and course achievement. In the winter semester of 2020/21, a sample of 144 Austrian university students participated in a survey with measurements at different points in time. Multiple linear regression was carried out to explore factors related to course achievement. The results indicate that gender, achievement-avoidance goals, academic self-concept, engagement in asynchronous learning, and course satisfaction were positively related to achievement. In contrast, work avoidance was identified as a barrier to achievement. Additionally, multivariate analysis of variance (MANOVA) was employed to test gender differences. MANOVA revealed significant gender differences regarding learning goals, mathematical self-concept, work avoidance, and engagement in synchronous learning. There were no gender differences regarding course satisfaction or achievement. The study has implications for designing innovative programming courses that could foster course satisfaction and achievement and thus reduce dropout and failure rates.

Keywords: programming education; online learning; flipped classroom; course achievement; gender differences



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1. Introduction

Increasing reliance on digital technologies in a multitude of life domains emphasizes the crucial role of programming in today's world as a 21st century skill. Programming skills are valuable across different study subjects and professions [1]. However, learning to program is a complex process, and students face various challenges when taking introductory programming courses (IPCs). Learning programming seems to be a bottleneck for students in the first semester, which impairs or even completely prevents the transition to higher semesters [2,3]. This seems to be particularly true for the already small proportion of women taking part in these subjects [3–5]. To identify factors related to persistence and achievement in programming education, previous studies have focused on students' self-beliefs (e.g., self-concept and self-efficacy), motivation, emotions, learning engagement, and satisfaction [1,4,6–11].

When investigating the significance of person-specific characteristics for learning, it is important to consider not only the content of learning but also the respective learning environment with a specific instructional approach. Prior research on learning and achievement in programming education highlights the importance of implementing a suitable approach [12–14]. Active learning methods combined with interactive technology may be beneficial in this context. They foster the flexibilization of education [15] and may improve learning experiences and learning outcomes and close the gender gap in IPCs [3,16,17]. Considering these benefits, a flipped classroom (FC) approach in programming courses [16–18], which addresses students' high acceptance of remote learning methods in an online setting [19], was chosen. Online flipped learning combines the strengths of online learning and flipped classrooms by providing asynchronous instructional content and synchronous interactive sessions. Although extensive research has been conducted on factors related to (a) online learning [20–22] and (b) flipped learning [23–25] independently, the integration of these approaches in the context of IPCs is less well explored. The present study aims to fill this gap by investigating how specific antecedents for learning (e.g., self-concept and students' goal orientations) and process variables (e.g., engagement in synchronous and asynchronous learning and course satisfaction) impact course achievement in a fully online FC setting in IPCs. Moreover, gender disparities in this context will be explored, offering new insights into the role of gender in online flipped learning environments.

1.1. The Flipped Classroom as a Learning Method in Programming Education

Programming is a fundamental skill in computer science and computing-related study fields. Hence, internationally, "Introduction to Programming" courses (IPCs) serve as a central component in the curricula of these studies [26]. IPCs are usually offered in the first year of study, aiming to equip students with fundamental programming knowledge. Traditionally, this course covers problem-solving skills, syntax and semantics, programming languages, logical thinking, and fundamental concepts of programming [27].

Learning to program increases not only technical skills but it also enhances the development of language skills, collaborative skills as well as creativity [28,29]. Also, the growing dependence on digital technologies across diverse aspects of life emphasizes the importance of programming in today's digital era. Nevertheless, the acquisition of programming skills is accompanied by various challenges. Difficulties are often related to deficits in problem-solving skills, mathematical abilities, or the ability for abstract thinking [27]. However, not only cognitive factors but also students' emotions and attitudes may endanger success and persistence [1,4,6].

Non-traditional learning methods and suitable learning environments may be beneficial in this context. Prior studies on programming learning show that such learning methods could positively impact students' emotions, motivation, and achievement and could reduce dropout and failure rates in IPCs [10,30].

Online learning is an example of a non-traditional learning method. Online courses in higher education may provide desirable instruction characteristics, such as flexibility to learn at one's own pace and schedule. Moreover, online learning fosters self-regulated learning, which promotes the students' autonomy in learning, supports various learning styles, and is related to learning achievement [18,31]. Another major advantage of online courses is easy access to learning resources, which creates a crucial basis for successful learning [32].

One instructional strategy that is efficiently integrated into many higher education classes is a student-centric learning method: the flipped classroom (FC) [23,33]. The central idea behind this concept is to reverse (i.e., to flip) the traditional instruction model, where students typically receive lectures during class time and then engage in individual work or homework outside of the classroom. Within the FC, students are able to actively take part in class activities. Usually, the FC model consists of two types of phases [16,34,35]:

- Asynchronous phases are when students engage with instructional content before (pre-class) or after class outside the classroom. In the pre-class phase, students are

encouraged to prepare for the in-class phase (i.e., synchronous phase) by engaging in self-directed learning using resources, such as lecture videos or online modules. In the after-class phase, students engage with instructional content after the synchronous phase using learning resources, such as quizzes, online tests, and self-evaluation.

- Synchronous phases (i.e., in-class phases) in which students and instructors meet face-to-face. In the classroom setting, students are encouraged to actively engage in classroom activities such as discussions, group work, or hands-on activities.

By incorporating these two types of phases, the FC promotes the development of competencies and knowledge construction through social collaboration, while also encouraging self-directed learning. Previous studies on programming education suggest that the FC is especially suitable for engineering classes in higher education since it focuses on problem-based learning, logical reasoning, and imaginative thinking [12,36]. Compared with traditional teaching methods, this method improves students' achievement in programming courses as well as their learning satisfaction [18,37].

During the COVID-19 pandemic, as a response to the digital transformation of education, a new variation of the FC method gained popularity in higher education: the fully online FC approach. This learning method represents an innovative student-centric approach that supports learning in an online setting. Similar to a conventional FC approach, the fully online FC method requires students to prepare for the class asynchronously using different online learning resources (e.g., completing quizzes, watching videos, and working with text materials). However, within synchronous phases, students and instructors meet online, not face-to-face [38,39]. In the present study, a fully online FC was utilized and explored within the context of an IPC. Such a concept caters to remote learners and was naturally a feasible scenario during the COVID-19 pandemic. However, there is a risk of decreased learner participation in the online setting. Previous studies suggest that learner-to-instructor engagement, i.e., offering synchronous phases with a high level of interaction between students and lecturers, could enhance learner participation and engagement [40]. In the FC setting, providing feedback during the synchronous phases plays a key role in facilitating learning achievement [41]. In the current study, this was addressed by carefully designing synchronous phases with high levels of interaction between the students and the lecturer team. Additionally, all students had access to online tutor support, offering an additional platform for discussion and feedback.

1.2. Course Structure

The course's main objective is that students acquire a solid foundation in programming principles and the C programming language. Due to the high number of students enrolled in the course and the COVID-19 restrictions, it has been held as a fully online FC course since 2020.

This IPC included two parts:

- (1) Asynchronous part: As a vital component of the lecture, each week, on Friday afternoon, students were provided with 5–15 min video clips via the university's learning management system. These videos were recordings of the same lecture from the previous semesters, which were edited and cut down into small segments, with each video covering one concept of the lecture. This part of the course was based on the lecture concept, and therefore, the previous written materials (explanations, tasks, etc.) were also adopted. These asynchronous elements served as preparation for the synchronous lecture units.
Various measures were taken to encourage participant engagement, such as sample tasks for practicing and assessing learning gains but most importantly, assignments that had to be submitted at three points.
- (2) Synchronous part: Each Thursday, a 90 min synchronous online lecture was held using the Twitch streaming platform. The lecture was attended by an average of about 150 students each week. Twitch is known for its lively discussions between streamers and the community. The platform enables several built-in tools for interactions, such

as polls, votes, or chat commands to engage the audience. It also gained popularity in educational streams, especially in the context of STEM education [42]. The course was attended by students from various degree programs. It was therefore necessary to create an opportunity for a larger group (>100 participants) to take part in direct, synchronous communication. The synchronous phases were therefore held by two lecturers with the support of two tutors. During the live streams, two lecturers and two tutors briefly repeated the concepts from the asynchronous videos and presented further examples and explanations to provide the students with diverse perspectives. Then, different direct communication options were made available. In some phases, the participants were able to ask questions in a large group, which were then answered by the lecturer or the tutors. Each lecture included specific time points where questions from the chat or audience response tools were gathered and answered. In addition, one of the lecturers and several tools were available in the chat and answered questions, but they also encouraged conversation between students. There was also the opportunity during additional (virtual) consulting hours to discuss tasks and their solutions in a smaller group with a tutor or lecturer. Students could ask questions within the Twitch community chat or through the audience response system Mentimeter.

Over the entire semester, the students individually worked on three equally important assignments, all of which had to be passed successfully. The level of complexity increased from assignment to assignment and the covered concepts built on each other.

1.3. Personal Characteristics and Attitudes Related to Learning and Achievement in the Academic Context

Learning is a dynamic and multifaceted process shaped by three interrelated components: presage, process, and product factors [43]. Presage factors refer to personal antecedents of learning that exist before the learning process begins, e.g., students' abilities, motivation, beliefs (e.g., self-concept and self-efficacy), and attitudes. Motivational factors and self-concept are particularly important because they influence each other reciprocally over time and influence learning behavior, learning emotions, and strategy use [44]. The process component describes strategies employed during the learning experience. This includes teaching methods, the learning environment as well as the learner's engagement. Learning outcomes such as academic achievement, test scores, or skill development are considered product variables [45]. In this study, factors related to learning and achievement in an academic context were chosen based on previous research [32,44,46,47] and, derived from the 3P model [43], categorized into personal antecedents, i.e., presage factors and process variables. Course achievement is considered a product variable.

1.3.1. Personal Antecedents of Learning and Achievement

Academic goal orientations describe individuals' cognitive representations of the reasons for their engagement in specific academic activities and can be distinguished into:

- Mastery or learning goal orientations refer to competence improvement and development while using self-referenced standards of improvement. Students who are more oriented toward learning goals show more adaptive achievement behaviors in an academic context, such as using self-regulation strategies while learning or feedback-seeking [48,49].
- Achievement goal orientations that focus on the demonstration of competence relative to others and can be categorized into achievement-approach (focus on demonstrating competence and superiority) and achievement-avoidance (focus on avoiding failure and judgments for incompetence) goals [50,51].
- Work avoidance which represents an additional type of goal orientation and can be defined as a goal to "consistently avoid putting in an effort to do well, do only the minimum necessary to get by, and avoid challenging tasks" [52]. Therefore, work avoidance could be described as the absence of an achievement goal.

Goal orientations are important predictors of various academic outcomes, such as learning satisfaction, self-regulated learning, use of deep learning strategies, engagement in learning, motivational tendencies, and academic achievement [47,53,54]. In programming education, learning goal orientation as well as achievement approach are related to better achievement in programming courses [55].

Self-concept can be described as an individual's self-assessments formed through experience with and interpretations of one's environment [56]. Academic self-concept is a part of the general self-concept that refers to a person's self-perceptions and self-evaluations in an academic context. Mathematical self-concept refers to a self-concept in the specific knowledge domain and it comprises a perception and evaluation of one's competencies and abilities as well as feelings of self-confidence regarding mathematics. Both academic (i.e., general) and mathematical (i.e., domain-specific) self-concepts are positively related to a broad range of outcomes in an academic context, including academic achievement and learning satisfaction [11,32,44,57]. Additionally, in a study involving predominantly university students with science/engineering majors, academic self-concept was identified as an important precursor of academic achievement and generic skills development [58].

Students' gender is also an important antecedent for learning and achievement in an academic context. It correlates with other antecedents for learning, such as academic self-concept, learning strategies, self-efficacy, and motivation, and is also related to academic achievement [32,44,46]. In their systematic review, Wang and Yu [59] demonstrated that gender moderates the relationship between self-concept and students' motivation and performance. They found that, particularly in STEM domains, female students show lower levels of domain-specific self-concept, which is related to lower motivation and poorer performance in these fields. Additionally, recent research on online learning emphasizes gender as an important antecedent for learning. For example, Wang et al. [60] identified gender disparities in online courses in the sense that women paid more attention to their achievement feedback.

1.3.2. Learning Engagement, Satisfaction, and Academic Achievement

Learning engagement describes how involved or interested students are in learning and defines how they are connected to both their class and each other [61]. Students' involvement or engagement is a crucial process variable in the learning process. Engaged students are more likely to complete a course and show better achievement [62]. Furthermore, studies on programming learning have shown a positive relationship between students' learning engagement and the attainment of higher-order thinking skills [63]. How and to what extent learners engage with and address learning content depends on various factors, including their learning performance motivation and self-assessment of their ability to succeed in the learning process [40,58]. It is particularly crucial for students to engage in all phases of learning. The success of the collaborative phase with peers and instructors heavily relies on effective preparation during the self-learning phases [39]. In online education settings, engaged students are more satisfied with courses [8].

Course satisfaction is a multi-dimensional concept related to various antecedents, processes, and product factors in the learning context [61]. It is positively related to a number of learning outcomes, such as skill development, course participation, and academic achievement [8]. In the context of programming education, using the FC approach could be beneficial in increasing students' course satisfaction and achievement (for meta-analysis, see [18]).

1.3.3. Gender Differences in Programming Education

The dominance of one gender in a study field can be connected to greater gender disparities in this particular field [59,64]. This is also true for traditional IPCs [5]. There are still fewer women than men choosing to study computer science [65,66]. Within traditional IPCs, gender differences manifest in self-assessments of learning achievements, learning behaviors, and partly even skill development [67]. Female students often assess

programming as being difficult, report lower intentions to program in the future, or assess themselves more critically [3,68]. They often respond to achievement feedback early in the IPC, incorporate it overly self-critically into their self-concept, and, hence, tend to revisit their programming self-beliefs earlier in the course, which consequently hinders their later programming engagement [4,69]. When they achieve the same results as their male colleagues, women are more likely to underestimate their performance [70].

In this context, learning methods and learning environments in IPCs play a major role. Introducing innovative and unconventional pedagogical approaches, along with varied learning environments, may enhance gender equality in IPCs [5,10,71–73]. However, prior research has been mainly focused on course satisfaction and course achievement in the context of innovative programming learning concepts; the impact of non-traditional learning approaches on different presage and process factors has been underexplored.

1.4. Research Questions

Flipped classroom (FC) settings have been widely recognized for their benefits in various educational aspects, such as enhancing student engagement, improving learning outcomes, and fostering active learning [16–18]. Despite these advantages, there is limited research specifically exploring the factors that impact learning in a fully online FC setting, particularly in the domain of programming education. Based on the theoretical background and prior research described above, the following research questions were addressed:

1. To what degree may antecedents for learning support or impair achievement in an IPC in an online FC setting?

Antecedents for learning: As described in Section 1.3.1., goal orientations, academic self-concept, mathematical self-concept, and gender are important antecedents for learning and achievement in an academic context. Therefore, it is assumed that these factors are related to achievement in an IPC in an online FC setting.

2. To what degree may process variables support or impair achievement in an IPC in an online FC setting?

Process variables: As described in Section 1.3.2., engagement in synchronous and asynchronous learning and course satisfaction are important process variables in (online) education. Therefore, it is assumed that these variables are related to achievement in an IPC in an online FC setting.

In traditional IPCs, female and male students differ in their self-beliefs as well as in their learning outcomes, with male students showing higher levels of self-efficacy [74] and better achievement [3,4,75,76]. Implementing innovative learning methods and non-traditional learning environments could promote gender equality in self-beliefs and learning outcomes in the context of programming learning [3,5,10,75,76]. Against this background, the third research question was formulated:

3. Do the female and male participants differ regarding antecedents for learning, process variables, and course achievement?

2. Methodology

2.1. Participants

At Graz University of Technology, each semester, about 800 students from all computer science-related studies (computer science, software engineering, etc.) are enrolled in the IPC. In the investigated course, a total of 636 students participated actively. They were contacted via email and asked to participate in two online surveys (t1 and t2). Altogether, 144 students participated in both surveys and completed the programming course. The sample includes 23 women (15.97%) and 121 men (84.03%), reflecting the gender composition within the chosen study fields at Graz University of Technology. The age of the participants ranged from 18 to 40 years ($M = 21.26$; $SD = 3.24$).

2.2. Instruments

Over the semester, two questionnaires were sent out to the students, one at the beginning of the semester and one at the end of the semester (available for download as Supplementary Material for non-commercial use). The first questionnaire (t1) covered personal antecedents for learning and achievement. The aim of the second data collection stage (t2) was to assess process variables. A summary of the respective instruments, sample items, rating scales, and Cronbach's alphas is presented in Table 1.

Table 1. Summary of instruments, sample items, rating scales, and Cronbach's alphas.

Instrument/Measurement	Variable	Sample Item	Rating Scale	Internal Consistency (α)
SELLMO (scales for motivation to learn and to achieve; [77])	Work avoidance	"In my studies it is important to me to do as little work as possible."	1 (totally disagree) to 5 (totally agree)	$\alpha = 0.88$
	Learning Goals	"In my studies it is important for me to learn as much as possible."		$\alpha = 0.89$
	Achievement-approach Goals	"In my studies it is important to me that others think I am smart."		$\alpha = 0.75$
	Achievement-avoidance Goals	"In my studies it is important to me not to embarrass myself, e.g., by giving wrong answers or asking dumb questions."		$\alpha = 0.92$
SASK (scales for motivation to learn and to achieve; [78])	Academic self-concept	"Considering the demands of my studies, I regard my academic abilities as ..."	1 (low) to 7 (high)	$\alpha = 0.82$
Self-developed items based on SASK (scales for motivation to learn and to achieve; [78])	Mathematical self-concept	"Compared to my colleagues my skills in mathematics are ..."	1 (less skilled) to 5 (very skilled)	$\alpha = 0.81$
Self-developed Items	Engagement in asynchronous learning	"How often did you watch the learning videos provided in the learning management system before the lecture streams?"	6 = watched/attended almost all units, 5 = watched/attended about 75% of the units, 4 = watched/attended about 50%, 3 = watched/attended about 25%, 2 = watched/attended single units, and 1 = none.	(1-item-scale)
	Engagement in synchronous learning	"How often did you attend online lectures?"		(1-item-scale)
	Course satisfaction	"Overall, I am ... with the course."	1 (not satisfied) to 6 (very satisfied)	(1-item-scale)

Students' goal orientations (t1) were assessed using 31 items of the self-report measure SELLMO [77]. The SELLMO is a proven, reliable survey instrument that has been widely used and whose validity in terms of correlations with important parameters of learning and instruction has been proven in numerous studies [79,80]. It contains four differentiated subscales measuring learning goals, achievement-approach goals, achievement-avoidance goals, and work avoidance.

Academic self-concept (t1) was assessed using three items from three subscales of the SASK (Scales Academic Self-Concept) [78], which measures an academic self-concept relating to an external frame of reference. SASK was chosen because of its validity and reliability and the possibility of using it for specific domains [81,82]. Students assessed their study abilities and their study-related skills compared to the requirements and demands of their study subject on a 7-point Likert scale. On the same scale, they gave an assessment of their study abilities compared to their fellow students.

Mathematical self-concept (t1) was measured using three adapted SASK items. Students assessed their mathematical skills generally and during their school time as well as compared to their fellow students on a 5-point Likert scale ranging from 1 (less skilled) to 5 (very skilled).

Engagement in asynchronous learning (t2), engagement in synchronous learning (t2), and course satisfaction (t2) were measured with single items at the end of the course.

Course achievement represents the total sum of points in the three programming assignments. The students worked individually on the programming tasks. The first assignment covered basic concepts of programming, whereas the second and the third

included more advanced topics. Points for the three achievements were summed up (0 to a maximum of 30 points on the first assignment, 0 to 33 points for the second assignment, 0 to 37 points for the third assignment, and 0 to 6 bonus points for additional activities). In total, students could reach between 0 and 106 points.

2.3. Data Collection and Analysis

Data were collected at several time points during the winter semester of 2020/21 at Graz University of Technology. Course achievement was based on the total sum of points in the three programming assignments. Points of data collection for variables of interest are represented in Table 2.

Table 2. Points of data collection for variables of interest.

Time Point	Variable Group	Variable
t1 (survey) 28th October until 7th November 2020	Antecedents	Gender Work avoidance Learning goals Achievement-approach goals Achievement-avoidance goals Academic self-concept Mathematical self-concept
t2 (survey) 21st January 2021 until 2nd February 2021	Process Variables	Engagement in asynchronous learning Engagement in synchronous learning Course satisfaction
Assignment 1 (November 2020) Assignment 2 (December 2020) Assignment 3 (January 2021)	Outcome	Course achievement

Data collection was conducted via LimeSurvey. LimeSurvey was chosen as the tool for conducting our online survey due to its comprehensive features and user-friendly interface. It allows for the creation of complex surveys with various question types and advanced branching logic, ensuring that the survey can be tailored to our specific research needs. Additionally, LimeSurvey provides robust data security measures, ensuring the confidentiality of participant responses. Its wide acceptance in academic research further underscores its reliability and effectiveness as a survey tool. Data analysis was performed in the R programming language and SPSS 28. The study was performed in accordance with the American Psychological Association's Ethics Code and the Declaration of Helsinki.

3. Results

3.1. Descriptive Statistics

Descriptive statistics for the investigated variables are presented in Table 3.

Table 3. Descriptive statistics by gender (M, SD, Md, Min, Max, and Range).

	M	SD	Md	Min	Max	Range
Course achievement (all)	77.62	16.98	78.89	19.41	106.00	
Men	78.21	16.94	80.65	24.70	106.00	0–106
Women	74.49	17.22	72.01	19.41	99.12	
Work avoidance (all)	1.80	0.72	1.63	1.00	4.75	
Men	1.85	0.73	1.75	1.00	4.75	1–5
Women	1.52	0.59	1.38	1.00	3.00	

Table 3. Cont.

	M	SD	Md	Min	Max	Range
Learning goals (all)	4.32	0.68	4.50	1.50	5.00	1–5
Men	4.26	0.71	4.50	1.50	5.00	
Women	4.60	0.48	4.75	2.88	5.00	
Achievement-approach goals (all)	2.91	0.71	2.93	1.14	4.71	1–5
Men	2.92	0.74	2.86	1.14	4.71	
Women	2.88	0.57	3.00	1.71	4.29	
Achievement-avoidance goals (all)	2.07	0.86	1.88	1.00	5.00	1–5
Men	2.05	0.85	1.86	1.00	5.00	
Women	2.21	0.95	1.75	1.25	4.13	
Academic self-concept (all)	4.58	0.83	4.67	2.66	6.66	1–7
Men	4.60	0.82	4.66	2.66	6.66	
Women	4.43	0.90	4.00	3.33	6.33	
Learning goals (all)	4.32	0.68	4.50	1.50	5.00	1–5
Men	4.26	0.71	4.50	1.50	5.00	
Women	4.60	0.48	4.75	2.88	5.00	
Achievement-approach goals (all)	2.91	0.71	2.93	1.14	4.71	1–5
Men	2.92	0.74	2.86	1.14	4.71	
Women	2.88	0.57	3.00	1.71	4.29	
Achievement-avoidance goals (all)	2.07	0.86	1.88	1.00	5.00	1–5
Men	2.05	0.85	1.86	1.00	5.00	
Women	2.21	0.95	1.75	1.25	4.13	
Academic self-concept (all)	4.58	0.83	4.67	2.66	6.66	1–7
Men	4.60	0.82	4.66	2.66	6.66	
Women	4.43	0.90	4.00	3.33	6.33	
Mathematical self-concept (all)	3.62	0.74	3.66	1.00	5.00	1–5
Men	3.56	0.72	3.66	1.00	5.00	
Women	3.97	0.76	4.00	2.66	5.00	
Engagement in asynchronous learning (all)	3.98	1.56	4.00	1.00	6.00	1–6
Men	3.88	1.58	4.00	1.00	6.00	
Women	4.48	1.41	5.00	1.00	6.00	
Engagement in synchronous learning (all)	4.79	1.49	5.00	1.00	6.00	1–6
Men	4.92	1.39	5.00	1.00	6.00	
Women	4.13	1.82	4.00	1.00	6.00	
Course satisfaction (all)	5.01	0.96	5.00	2.00	6.00	1–6
Men	4.98	0.96	5.00	2.00	6.00	
Women	5.17	0.98	5.00	3.00	6.00	

Note. Lower numbers indicate lower values in a particular variable/factor. The variable gender is coded as m = 1 and w = 0. M, mean; SD, standard deviation; Md, median; Min, minimum; Max, maximum. The sample size for all variables N = 144.

Bivariate correlations between variables are shown in Table 4.

Table 4. Bivariate correlations between variables.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Course achievement	1.00										
2. Gender	0.08	1.00									
3. Work avoidance	−0.23 **	0.17 *	1.00								
4. Learning goals	0.14	−0.18 *	−0.61 ***	1.00							
5. Achievement-approach goals	0.09	0.02	0.01	0.30 ***	1.00						
6. Achievement-avoidance goals	0.11	−0.07	0.47 ***	−0.27 **	0.44 ***	1.00					
7. Academic self-concept	0.35 ***	0.07	−0.18 *	0.09	0.26 **	0.13	1.00				
8. Mathematical self-concept	0.29 ***	−0.21 *	−0.08	0.08	0.15	0.21 *	0.39 ***	1.00			
9. Engagement in asynchrony learning	0.21 *	−0.10	−0.06	0.14	0.09	0.04	−0.08	0.14	1.0.		
10. Engagement in synchronous learning	0.17 *	0.19 *	0.02	−0.06	−0.15	−0.07	−0.07	0.08	0.36 ***	1.00	
11. Course Ssatisfaction	0.23 **	−0.07	−0.08	0.16	0.12	0.11	0.17 *	0.11	−0.01	0.01	1.00

Note. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

3.2. Factors Related to Course Achievement

To address research questions 1 and 2, multiple linear regression analysis was employed, with course achievement in an online FC setting as the dependent variable. This method was selected due to its ability to determine the extent to which multiple independent variables (antecedents for learning and process variables) can predict the variance in a dependent variable, allowing the unique contribution of each antecedent and process variable to course achievement to be quantified. Independent variables were gender, work avoidance, learning goals, achievement-approach goals, achievement-avoidance goals, academic self-concept, mathematical self-concept, engagement in synchronous and asynchronous learning, and course satisfaction. The results are presented in Table 5.

Table 5. Summary of the linear regression with standardized coefficients (β) and standard errors (SE).

	Course Achievement		
	β	SE	<i>p</i> -Value
Antecedents			
Gender	0.173 *	3.770	0.036
Work avoidance	−0.283 **	2.497	0.008
Learning goals	0.013	2.608	0.903
Achievement-approach goals	−0.115	2.297	0.236
Achievement-avoidance goals	0.232 *	2.020	0.025
Academic self-concept	0.229 **	1.766	0.009
Mathematical self-concept	0.132	1.943	0.121
Process Variables			
Engagement in asynchronous learning	0.182 *	0.760	0.027
Engagement in synchronous learning	0.079	0.946	0.340
Course satisfaction	0.155 *	1.333	0.042
R ²	0.302		

Note. * $p < 0.05$; ** $p < 0.01$. The variable gender is coded as m = 1 and w = 0.

Six variables contributed to course achievement. Five variables obtained positive β -weights (gender, achievement-avoidance goals, academic self-concept, engagement in asynchronous learning, and course satisfaction) and were thus positively related to course achievement. Work avoidance was negatively related to course achievement. Altogether, approx. 30% of the variance could be explained by the regression model.

3.3. Gender Differences in the FC Online Programming Course

To test gender differences regarding antecedents for learning, process variables, and course achievement in an online FC setting (research question 3), a multivariate analysis of variance (MANOVA) was carried out. MANOVA was selected because it allows for the simultaneous examination of multiple dependent variables and the detection of gender differences across these variables. In this context, MANOVA enables the assessment of the overall impact of gender on the variables of interest and determines if significant differences exist between female and male participants. The results of the present analysis show a significant multivariate effect of gender on the combined dependent variables, $\Lambda = 0.76$, $F(10, 133) = 4.14$, $p < 0.001$, $\eta^2 = 0.237$). Women scored significantly higher than men in learning goals, $F(1, 142) = 4.798$, $p < 0.05$, $\eta^2 = 0.033$ and mathematical self-concept, $F(1, 142) = 6.292$, $p < 0.05$, $\eta^2 = 0.042$. Men scored significantly higher than women in work avoidance, $F(1, 142) = 4.193$, $p < 0.05$, $\eta^2 = 0.029$, as well as in engagement in synchronous learning, $F(1, 142) = 5.558$, $p < 0.05$, $\eta^2 = 0.038$. There were no significant differences between female and male students regarding achievement-approach goals, $F(1, 142) = 0.050$, $p > 0.05$, $\eta^2 = 0.000$, achievement-avoidance goals, $F(1, 142) = 0.648$, $p > 0.05$, $\eta^2 = 0.005$, academic self-concept, $F(1, 142) = 0.792$, $p > 0.05$, $\eta^2 = 0.006$, engagement in asynchronous

learning, $F(1, 142) = 1.488, p > 0.05, \eta^2 = 0.010$, course satisfaction, $F(1, 142) = 0.385, p > 0.05, \eta^2 = 0.005$, or course achievement, $F(1, 142) = 0.927, p > 0.05, \eta^2 = 0.006$.

4. Discussion

4.1. Factors Related to Achievement in the Online FC Programming Course

As expected, students who scored higher on work avoidance, e.g., who felt disengaged and indifferent toward course-related activities, showed lower course achievement. Work avoidance was not strongly pronounced among the students overall. However, even slight increases in work avoidance already impact academic achievement. This result is in line with the control–value theory [83] and the expectancy–value theory [84], suggesting that attaching a high value to an academic goal is a crucial precondition for achieving it. Students who appraise a particular academic goal as important, adopt more self-regulated learning strategies [85], and experience more positive emotions while learning [83,86,87] are more likely to achieve their goals [87–89].

Based on prior research, one might expect that students who focus on avoiding failure and judgments also avoid challenging situations in which low ability can be demonstrated, which consequently leads to lower academic engagement [90] and poorer academic achievement [53,91]. Surprisingly, in the current investigation, achievement-avoidance goal orientation was related to better course achievement. It appears that the goal of avoiding failure and judgments for incompetence could also be achieved by actively dealing with the stressor and not by disengagement, i.e., by escaping the task (similar to [47]). In this case, achievement-avoidance goal orientation would still prevent negative outcomes, but it may be related to negative emotions and a higher level of tenseness [47]. Contrary to expectations, learning and achievement-approach goal orientations were not related to course achievement. It seems that successful students did not use functional but rather dysfunctional goal orientation (achievement avoidance). Considering that dysfunctional goal orientations are connected to experiencing more negative emotions in the learning process [47], this could pose a hazard to students' long-term learning experiences. Another possible explanation might be that, in an online setting, specific task goals, rather than general learning goals, are more beneficial for learning achievement [20].

Positive academic self-concept contributed to better course achievement. Consistent with previous research, students who assessed their study-related skills as high showed better academic achievement [11,92,93]. Rather unexpectedly, mathematical self-concept was not related to course achievement in the programming course. It might be that a subject-specific self-concept, i.e., assessments of study-related skills and ability, plays a more important role in the context of computing-related studies [94].

The significant relationship between gender and course achievement in this study indicates lower achievement among female students. However, female students did not differ significantly from their male colleagues regarding course achievement. It seems that functional goal orientations among female students (less work avoidance and more learning orientation compared to male students) played a crucial role in outbalancing disadvantages in programming learning.

Students engaged in asynchronous learning were more likely to succeed in the course, whereas students' engagement in synchronous learning was not connected to their course achievement. It seems that active participation in the synchronous online interaction had less impact on achievement. In FC settings, students acquire their knowledge base during the self-directed learning phases, which is then discussed, consolidated, and deepened in the synchronous in-class settings. These results emphasize the importance of providing adequate learning resources in the learning process [32] and show the advantages of the asynchronous, motivating, and stimulating elements of the FC. In the present setting, lecture videos were a crucial component in the asynchronous phases. Förster et al. [14] also point out that didactically well-prepared pre-class videos are beneficial for students' course achievement as well as for long-lasting learning success.

Overall, students reported high satisfaction with the online FC programming course. Students who were more satisfied showed better achievement. Fan et al. [13] made similar observations in an FC course and argue that students' acceptance is related to the advantages of asynchronous learning elements, including self-paced and flexible learning. Also, in their meta-analysis, Almassri and Zaharudin [18] showed that using the FC approach increases learning satisfaction and achievement in programming education.

4.2. Gender Differences in the FC Online Programming Course

Regarding gender differences in goal orientations, female students were more learning oriented whereas male students were more work avoidance oriented. D'Lima et al. [95] observed similar disparities among first-year students in introductory courses, with gender differences increasing over a semester. Interestingly, even though male students were more oriented toward work avoidance, they showed higher levels of engagement in the synchronous learning phases compared to female students. This result is contrary to previous research demonstrating that pursuing work avoidance goals is related to less engagement in an academic context [52,96]. However, the present study was conducted within an online learning setting. Thus, the findings of the current study emphasize the importance of considering different types of learning engagement in the context of online education. It seems that in this setting, male students are more likely to actively participate (similar to [97]). However, engagement in this learning phase was less significant for success.

Gender differences in self-concept especially concern mathematical self-concept, with female students showing higher values compared to their male colleagues. In line with previous studies, mathematical self-concept was a key predictor of the pursuit of STEM subjects with a low proportion of women [98,99]. Apparently, only women who are confident regarding their mathematic abilities opt for STEM subjects, with a low proportion of females. Mathematical self-concept, however, was not a significant predictor of course achievement. It seems that the positive attitudes that females might have in terms of their mathematical skills (and probably former achievements in school as self-concept is at least to a middle degree related to former achievement) did not translate into their learning of programming.

There were no gender differences regarding course satisfaction or course achievement, implying that the online FC learning approach could be beneficial for both female and male students. Hence, it may promote closing a gender gap in learning outcomes within IPCs and consequently reduce dropout and failure rates.

4.3. Limitations

In total, 144 out of 636 enrolled students (22.64%) participated in both surveys. This small sample size could limit the generalizability of the current findings. Furthermore, the current study relied on voluntary participation, e.g., students chose to participate in the current study based on their own motivations. This non-random sampling method can introduce systematic differences (participants in the current study may differ systematically from the population of interest), which may compromise the external validity of our findings, limiting their generalizability. Future research should consider applying strategies, e.g., other recruitment methods, to mitigate self-selection bias. Also, despite efforts to minimize response bias through the implementation of common measures—such as ensuring survey anonymity, employing standardized questionnaires with neutral and clear wording, using balanced response scales, and encouraging honest and complete responses by explaining the survey's importance for educational improvements—some degree of bias may still be present. These factors should be considered when interpreting the findings. An additional limitation of this study is the reliance on a single item to measure synchronous and asynchronous engagement as well as course satisfaction. While this approach provided valuable insights, it may not fully capture the complexity of these constructs. A mixed-methods approach would have been more robust, combining quantitative measures with

qualitative data. For instance, in addition to surveys, methods such as interviews or focus groups could provide deeper insights into student engagement and course satisfaction. Furthermore, incorporating learning analytics and observational data could enhance the accuracy of the findings. Future research should consider these methodologies to obtain a more comprehensive understanding of student learning engagement and course satisfaction in online FC settings. Despite the above-mentioned limitations, the results of the present study provide valuable insights into the benefits of an innovative programming learning approach.

4.4. Implications for Practice

Based on the findings of the current study, the following implications for instructors and students can be derived:

Identified as a protective factor for learning and achievement, academic self-concept regarding study-related skills can be facilitated through feedback [59]. Encouraging self-directed learning along with specific feedback on assignments seems beneficial for the development of a positive (but realistic) academic self-concept in online learning environments [15].

Also, when designing future programming courses, instructors should consider the hazard of dysfunctional goal orientations (in the present study especially work avoidance). In the learning environment, focus should be directed not only toward achievement but also toward learners' emotions in a learning situation [32,44]. Instructors may enhance the development of functional goal orientations and positive learning emotions by creating a learning-oriented environment in which an open error culture is promoted and fear of failure is reduced. Furthermore, instructors are advised to promote the personal relevance of learning content among students, which could have a positive impact on students' intrinsic motivation and diminish the pursuit of minimal effort in learning. For example, instructors may highlight the practical significance of the learning content by emphasizing its real-world applications. Also, using FC approaches in higher education may increase students' intrinsic motivation [100].

The results speak for the use of fully online FC settings (similar to [39]). Overall, course satisfaction was very high (see Table 3). The use of asynchronous learning resources played a key role in successful programming learning. In the study, video clips were made available for this purpose, which the students could work on at any time and watch repeatedly. Previous studies [19] show that students are highly motivated to learn with this type of learning material. Therefore, instructors, as well as higher education institutions, are advised to provide adequate e-learning resources (similar to [101]) and promote flexible learning (see also [102]).

Finally, the findings reveal no significant gender disparity in course satisfaction and achievement, which underscores the efficacy of the fully online FC in ensuring equitable learning experiences for both male and female students. This highlights the potential of the employed learning approach to promote gender equality in IPCs.

However, there is still room for improvement in terms of more gender-sensitive didactics, e.g., a stronger focus on learning goal orientation or support for the study-related self-concept.

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