Assessing Students Cognitive and Affective Characteristics in Programming-Based Making Activities

Authors Name/s per 1st Affiliation *(Author)*
line 1 (of *Affiliation*): dept. name of organization
line 2: name of organization, acronyms acceptable
line 3: City, Country
line 4: e-mail: name@xyz.com

Authors Name/s per 2nd Affiliation *(Author)*
line 1 (of *Affiliation*): dept. name of organization
line 2: name of organization, acronyms acceptable
line 3: City, Country
line 4: e-mail: name@xyz.com

***Abstract*—This study aims to explain young students' intention to participate in programming-based making activities by examining the interrelations among cognitive characteristics (i.e., perceived usefulness, perceived ease of use) and affective characteristics (i.e., enjoyment) for both boys and girls. To this end, we build on complexity theory and configuration theory, present a conceptual model, and employ fuzzy-set Qualitative Comparative Analysis (fsQCA) on a sample of 105 young students, to identify the aforementioned interrelations. The findings indicate different combinations of the examined variables, and identify how the examined factors may have a different role for boys and girls. We take a step further the literature of programming-based making activities by employing a different methodology, one that has recently started to receive increasing attention.**

Keywords- programming; making; young students; computer science education; fsQCA

I. Introduction

Participation in programming among young students has received increased attention recently [1], and there is a need to make programming more informal and approachable, in order to be a more natural activity [2]. The majority of the students use their computers daily for multiple activities, however most of them are not aware of what is programming, as well as its relation with critical thinking, creative problem solving and computational thinking.

Young students create interactive stories games or animations by using visual programming tools (e.g., Scratch) in order to learn programming. In order to increase participation in programming among young students various attempts have been made to design joyful making activities [3], with specific focus given on female students [2]. The number of girls in programming is lower than that of boys, and recent reports suggest that fewer women intend to choose computing as a career compared to men [4], thus increasing the poor representation of females in the field. Studies in the area have also investigated the difference in the behavior of boys and girl [5, 6], as well as the reasons why girls are underrepresented in computing, and the findings indicate that it is not a matter of ability, instead further work is needed to identify factors that can help reducing gender differences in computing [2].

Previous studies in the area of learning programming have examined various ways that may influence young students' intention to participate in making activities [7]. Different factors have been identified as important when examining young students behaviour and attitude towards programming-based activities, including cognitive and affective characteristics such as confidence in their abilities, perceptions of ease of use, performance, enjoyment, and satisfaction [8, 9]. Surprisingly, only a few studies have focused on gender differences [7]. However, the majority of the studies in the area of programming focus on net effects among variables and employ variance-based approaches, which identify one single best solution, assuming that the relation among these variables is symmetrical. However, relations among variables are usually not fully symmetrical, instead a different relation between two variables may exist for different parts of a sample. Hence, more than one solutions may exist, explaining the outcome of interest, depending on how the examined variables combine with each other.

In this study, we focus on cognitive (i.e., perceived usefulness and perceived ease of use) and affective (i.e., enjoyment) factors, and aim to understand how they can explain high intentions to participate in programming-based making activities, for both boys and girls. Thus, we build on complexity theory and configuration theory and employ the novel fuzzy-set Qualitative Comparative Analysis (fsQCA) [10] in order to identify multiple solutions of variables that explain high intention to participate in programming activities. FsQCA is appropriate for explaining the complex interrelations among variables, as their combinations and interdependencies lead to the desired outcome [11, 12], and is suitable because it offers valid responses in studies with small samples [11]. FsQCA has received increased attention in different areas, such as business management [13], learning analytics [14] and others, and we build and expand on their contributions.

II. Background and Conceptual Model

Related work in the area of programming-based making activities has identified young students' positive attitude toward programming. Students' may show positive attitude and increased motivation, when they work on projects with visual programming, highlighting factors such as fun and usefulness [15]. In addition, young students' perception about cognitive characteristics, such as the easiness and usefulness of the activity, influence their intentions to participate in similar activities [16]. Affective characteristics, such as enjoyment and satisfaction, affect young students intention to participate in similar activities in the future [17, 18]. Moreover, users' attitudes and motivations of adopting technology-enhanced activities have been examined using the Unified Theory of Acceptance and Use of Technology (UTAUT) [18]. Previous studies show that when young students experience difficulties in programming, their excitement and enjoyment is reduced, but is increased when they successfully complete functional projects [19, 20],

Complexity theory and configuration theory build on the notion of *equifinality,* based on which a specific outcome may be explained by different, equally effective set of conditions (i.e., combinations of factors) [21]. Cognitive and affective characteristics are important causal conditions, in order to be able to better understand and explain young students' intention to participate in programming-based making activities in the future. These characteristics may combine with each other in different ways to explain students' intentions. Furthermore, configuration theory builds on the principle of causal asymmetry, based on which the presence or the absence of a condition (i.e., factor) from the output, depends on how this condition combines with the other conditions that are examined, in order to explain the desired outcome [12]. For example, boys and girls may have different perceptions regarding cognitive and affective characteristics, even if they show the same levels of behavioral intentions to participate in programming or similar activities in the future.

Even though programming is not a male activity, gender differences have been identified. Recent studies organized programming and designing activities for girls, indicating the importance of increasing happiness and decreasing anxiety during programming [16]. Similarly, a summer school was organized to reinforce high school girls' preference to attend college and consider computing as a career [22]. Thus, when examining the role of cognitive and affective characteristics it is critical to differentiate between boys and girls, in order to better explain their behavioural intentions.

The Venn diagram (Figure 1) illustrates the conceptual model of this study and presents three sets of constructs and their intersections. In detail, it shows the outcome of interest (dependent variable) and two sets of causal conditions to predict the outcome (independent variables). The outcome of interest is students' intention to participate in programming-based making activities in the future, and the two sets of causal conditions are cognitive characteristics (i.e., perceived usefulness, perceived ease of use) and affective characteristics (i.e., enjoyment). Their intersections represent factor configurations that are higher-level interactions. Specifically, the overlapped areas show areas where one factor may co-exist with the others. These possible combinations are able to explain a specific outcome, thus for example, all combinations explaining high intention to participate in programming-based making activities in the future are included within the outcome of interest area.

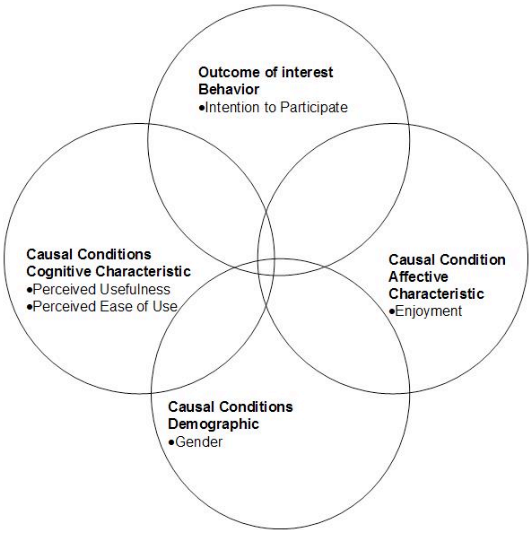

Figure 1. Venn diagram illustrating the conceptual model

III. METHODOLOGY

A. *Participants and procedure*

Seven programming workshops took place during Autumn 2015, and students from four different schools participated. In total, 128 students attended, consisted of 60 boys and 68 girls students. All workshops followed the same structure, having from 18 to 22 participants each. During the workshops, students interact with digital robots and then, create their own game using Scratch programming language. The goal was that students will successfully "give life" to the robots via programming and them develop a simple game (figure 2).

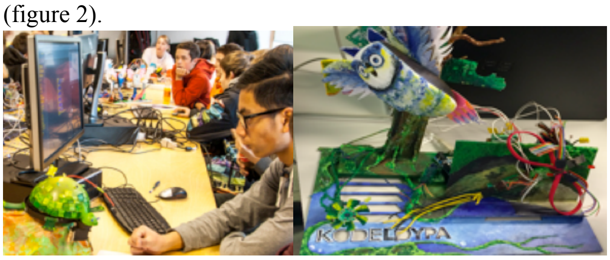

Figure 2. Students during the workshop (left), example of the digital robots used at the workshop

B. *Data collection and measures*

Across the seven workshops, a range of data was collected including surveys, photos and observations. For the purpose of this study we focused on the quantitative data. To collect the quantitative data, we conducted a post-survey based on questions adopted from similar studies in the literature. Students' responded to the survey at the end of the workshop day. In summary, we collected 105 responses (53.3% boys and 46.7% girls). Each attitude (construct) consisted of 3-4 questions (items) and measured using a 7-

point Likert scale. Table I presents the constructs of this study along with their definition and source in the literature.

TABLE I. CONSTRUCT DEFINITION

Construct	Definition	Source
Cognitive characteristic		
Perceived Usefulness	Represents the degree to which students believed that the programming-based making activity was useful for them	[23]
Perceived Ease of Use	Represents the degree to which students believed that attending the programming-based making activity was easy for them	[24]
Affective Characteristic		
Enjoyment	Represents the degree to which students believed that the programming-based making activity was enjoyable for them	[25]
Behavior		
Intention to participate	Which represent the degree to which students intent to participate in a similar activity in the future	[24]

C. Data Analysis

The constructs of this study were evaluated in terms of their reliability and validity. Reliability testing, based on Composite Reliability and Cronbach alpha, showed acceptable indices of internal consistency in that all constructs exceeded the cut-off threshold of 0.70. For validity, the average variance extracted (AVE) should be higher than .50, and the correlations among the variables in the confirmatory model should not exceed .8 points, the latter because exceeding 0.8 suggests low discrimination. The square root of each factor's AVE needs to be greater than its correlations with the other factors [26]. The AVEs for all constructs ranged between 0.55 and 0.80, all correlations were lower than 0.80, and the square root AVEs for all constructs were larger than their correlations. Next, we tested for multicollinearity [27] along with the potential common method bias by utilizing Harman's single-factor test [28]. The variance inflation factor for each variable was under 3, suggesting multicollinearity is not an issue. Findings indicate an absence of common method bias as the first factor did not account for the majority of the variance and no single factor occurred from the factor analysis.

D. FsQCA

To address its objective this study employs fsQCA using fs/QCA 2.5 [29], which was developed through the integration of fuzzy sets and fuzzy logic principles with Qualitative Comparative Analysis (QCA) [30]. By using fsQCA researchers go beyond traditional regression based analyses, as they identify multiple pathways that explain the same outcome. These pathways or combinations include variables that are not identified by regression based analyses because they influence the outcome only for a small number of cases [12]. The aforementioned combinations create to multiple solutions, offered by fsQCA, and each variable (or condition) may be present or absent on a solution, or it may be on a "do not care" situation. The "do not care" situation indicates that the variable may either be present or absent and it does not play a role on a specific configuration [21].

1) Data calibration

The next step is to calibrate all factors into fuzzy sets with values ranging from 0 to 1 [10]. This procedure may be direct or indirect. In the direct, the researcher chooses three qualitative breakpoints, while in the indirect, the factors should be rescaled based on qualitative assessments. Either method may be chosen depending on data and the underlying theory [10]. The direct method of setting three values that correspond to full-set membership, full-set non-membership and intermediate-set membership is recommended [10].

Data calibration here was done based on the direct method. Since our data is skewed to the right, choosing the three qualitative anchors for the calibration based on the survey scale (seven-point Likert scale) [13, 31] would not lead to meaningful results [32]. Thus, data calibration is done by using percentiles, that is the 80th percentile is the full-set membership, the 20th percentile is the full-set non-membership, and the 50th percentile is the intermediate set membership. Next, the values of each variable are calibrated on a linear function to fit into the three aforementioned breakpoints.

2) Truth table analysis

Next, fsQCA produces a truth table of 2^k rows, on which k represents the number of outcome predictors and each row represents every possible combination. The truth table should be sorted based on frequency and consistency (Ragin 2008). Frequency describes the number of observations for each possible combination, and consistency refers to "*the degree to which cases correspond to the set-theoretic relationships expressed in a solution*" [21]. A frequency threshold should be set to ensure that a minimum number of empirical observations is acquired for the assessment of the relationships. For samples larger than 150 cases the threshold should be set at 3, while for smaller samples the threshold may be set at 2 [10, 21], thus all observations with smaller frequency are removed from further analysis. Also, the threshold for consistency is set at .80, higher than the recommended threshold of 0.75 [33]. Observations above the consistency threshold are the ones that fully explain the outcome.

IV. FINDINGS

The findings from the fsQCA on the configurations for high intention to participate in a programming-based making activity in the future are presented in Table II. Every possible combination in the solution is able to explain the same outcome at a specific amount. In detail, the presence of a condition is depicted by black circles (●), while its absence by crossed-out circles (⊗) [21]. The blank spaces indicate a "do not care" situation, meaning that the causal condition may either be present or absent. Although, fsQCA identifies both core and peripheral elements here we include only core conditions since they are the ones that indicate strong causal relationship with the outcome, thus they present more interest. Table II also presents consistency values for every configuration as well as for the overall solution. All values are above the recommended threshold (>0.75). Consistency measures the degree to which a subset relationship has been approximated, while coverage assesses the empirical relevance of a consistent subset [33, 34]. The overall consistency is similar to the correlation. The overall solution coverage indicates the extent to which high intention to participate in a programming-based making activity may be determined from the existing configurations, and is comparable to the R-square value reported in traditional regression analyses. The overall solution coverage of .697 indicates that a substantial amount of the outcome is explained by the four solutions. FsQCA estimates also the empirical relevance for every solution, by calculating raw and unique coverage. The raw coverage describes the amount of the outcome that is explained by a certain alternative solution, while the unique coverage describes the amount of the outcome that is exclusively explained by a certain alternative solution. The solutions presented in Table II explain a great number of users' intention to participate in similar activities in the future, ranging from 11% to 47% cases associated with the outcome.

TABLE II. SOLUTIONS FOR HIGH INTENTION TO PARTICIPATE IN PROGRAMMING-BASED MAKING ACTIVITIES IN THE FUTURE

Configuration	1	2	3	4
Gender				
Boys	●	●		⊗
Cognitive Characteristic				
Perceived Usefulness			●	●
Perceived Ease of Use	⊗	●	●	⊗
Affective Characteristic				
Enjoyment	●	⊗	●	⊗
Consistency	.815	.774	.868	.782
Raw Coverage	.184	.195	.465	.108
Unique Coverage	.092	.082	.283	.051
Solution consistency: .787 Solution coverage: .697				

For high intention to participate in a similar activity in the future, the four solutions present different combinations for boys and girls, and also a combination on which the gender is not important, thus representing both boys and girls. In detail, for boys have high intentions, regardless of perceived usefulness, either (i) enjoyment should be present and perceived ease of use absent (Solution 1), or (ii) enjoyment to be absent and perceived ease of use present (Solution 2). Further, solution 3 explains the intentions for all students, on which both cognitive and affective characteristics need to be present (Solution 3). Finally, for girls intentions will be high, even when perceived ease of use and enjoyment are low, as long as perceived usefulness is high (Solution 4).

V. DISCUSSION

The present study proposes that in programming-based making activities, gender, cognitive and affective characteristics combine together to form configurations that explain students' intention to participate in these activities. To this end, we propose a conceptual model in order to visualize these combinations and explain their interrelationships. The findings describe how boys and girls students may have high intentions to participate in programming activities depending on how useful and easy they find the activity, or if they enjoy it. This study employs fsQCA, a novel analysis methodology, and identifies multiple complex patterns, on which cognitive and affective characteristics may be present or absent, depending on how they combine with each other.

Of particular interest in the findings is the role of perceived usefulness. In fact, perceived usefulness is present in 2 out of the 4 solutions (solutions 3-4) and when perceived usefulness is present high intention to participate in a programming-based making activity may be achieved even with the absence of all the other characteristics, when we have female students (solution 4). Interestingly, for boys (solutions 1-2) high intention to participate in a programming-based making activity may be achieved even with one of the perceived ease of use or enjoyment.

The results revealed that cognitive characteristics (e.g., usefulness), affective characteristics (enjoyment) play indeed an important role on students' intention to participate in a programming-based making activity may be achieved. The finding coincides with prior studies that adopted a TAM related approach (e.g., [16].

The majority of the studies in the area explain students' behavior by examining main effects among the various factors that may influence behavior. However, these factors may coexist and their combinations may lead to the same outcome. For example, enjoyment will influence young students high intentions to participate in programming activities, either it is high or low, depending on how it combines with perceived usefulness ease of use, and gender. This study makes a step towards creating new theories in computer science education, by employing fsQCA with complexity theory and configuration theory based on individual-level data from young students, which has been proven appropriate for theory building [12, 13].

Future studies should include other variables that affect the behavior of young students in programming-based making activities. Such factors, combined with demographics and experience may better predict behavior and direct researchers' and practitioners' focus. Also, future studies may examine a different outcome of interest, such as the actual time spent programming, and include more ways to measure students' behavior, such as eye tracking techniques [35].

REFERENCES

[1] Y. B. Kafai, Q. Burke, and M. Resnick, *Connected code: Why children need to learn programming*: Mit Press, 2014.

[2] L. Buechley, M. Eisenberg, J. Catchen, and A. Crockett, "The LilyPad Arduino: using computational textiles to investigate engagement, aesthetics, and diversity in computer science education," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2008, pp. 423-432.

[3] M. Guzdial, B. Ericson, T. Mcklin, and S. Engelman, "Georgia computes! An intervention in a US state, with formal and informal education in a policy context," *ACM*

Transactions on Computing Education (TOCE), vol. 14, p. 13, 2014.

[4] R. Lehming, J. Gawalt, S. Cohen, and R. Bell, "Women, Minorities, and Persons with Disabilities in Science and Engineering: 2013," *National Science Foundation, Arlington, VA, USA, Rep,* pp. 13-304, 2013.

[5] S. Avsec, D. Rihtarsic, and S. Kocijancic, "A predictive study of learner attitudes toward open learning in a robotics class," *Journal of science education and technology,* vol. 23, pp. 692-704, 2014.

[6] I. M. Verner and D. J. Ahlgren, "Robot contest as a laboratory for experiential engineering education," *Journal on Educational Resources in Computing (JERIC),* vol. 4, p. 2, 2004.

[7] S. Papavlasopoulou, M. N. Giannakos, and L. Jaccheri, "Empirical studies on the Maker Movement, a promising approach to learning: A literature review," *Entertainment Computing,* vol. 18, pp. 57-78, 2017.

[8] C. M. Lewis, "Is pair programming more effective than other forms of collaboration for young students?," *Computer Science Education,* vol. 21, pp. 105-134, 2011.

[9] M. N. Giannakos, "Enjoy and learn with educational games: Examining factors affecting learning performance," *Computers & Education,* vol. 68, pp. 429-439, 2013.

[10] C. C. Ragin, *Redesigning social inquiry: Fuzzy sets and beyond* vol. 240: Wiley Online Library, 2008.

[11] P. C. Fiss, "A set-theoretic approach to organizational configurations," *Academy of management review,* vol. 32, pp. 1180-1198, 2007.

[12] A. G. Woodside, "Embrace• perform• model: Complexity theory, contrarian case analysis, and multiple realities," *Journal of Business Research,* vol. 67, pp. 2495-2503, 2014.

[13] I. O. Pappas, P. E. Kourouthanassis, M. N. Giannakos, and V. Chrissikopoulos, "Explaining online shopping behavior with fsQCA: The role of cognitive and affective perceptions," *Journal of Business Research,* vol. 69, pp. 794-803, January 2016 2016.

[14] I. O. Pappas, M. N. Giannakos, and D. G. Sampson, "Making Sense of Learning Analytics with a Configurational Approach," in *Proceedings of the workshop on Smart Environments and Analytics in Video-Based Learning (SE@ VBL), LAK2016*, 2016.

[15] J.-M. Sáez-López, M. Román-González, and E. Vázquez-Cano, "Visual programming languages integrated across the curriculum in elementary school: A two year case study using “Scratch” in five schools," *Computers & Education,* vol. 97, pp. 129-141, 2016.

[16] M. N. Giannakos and L. Jaccheri, "What motivates children to become creators of digital enriched artifacts?," in *Proceedings of the 9th ACM Conference on Creativity & Cognition*, 2013, pp. 104-113.

[17] H.-P. Shih, "Using a cognition-motivation-control view to assess the adoption intention for Web-based learning," *Computers & Education,* vol. 50, pp. 327-337, 2008.

[18] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS quarterly,* pp. 425-478, 2003.

[19] K. Qiu, L. Buechley, E. Baafi, and W. Dubow, "A curriculum for teaching computer science through computational textiles," in *Proceedings of the 12th International Conference on Interaction Design and Children*, 2013, pp. 20-27.

[20] K. A. Searle, D. A. Fields, D. A. Lui, and Y. B. Kafai, "Diversifying high school students' views about computing with electronic textiles," in *Proceedings of the tenth annual conference on International computing education research*, 2014, pp. 75-82.

[21] P. C. Fiss, "Building better causal theories: A fuzzy set approach to typologies in organization research," *Academy of Management Journal,* vol. 54, pp. 393-420, 2011.

[22] J. E. Burge, G. C. Gannod, M. Doyle, and K. C. Davis, "Girls on the go: a CS summer camp to attract and inspire female high school students," in *Proceeding of the 44th ACM technical symposium on Computer science education*, 2013, pp. 615-620.

[23] M. J. Sanchez-Franco, "WebCT–The quasimoderating effect of perceived affective quality on an extending Technology Acceptance Model," *Computers & Education,* vol. 54, pp. 37-46, 2010.

[24] M. N. Giannakos and P. Vlamos, "Educational webcasts' acceptance: Empirical examination and the role of experience," *British Journal of Educational Technology,* vol. 44, pp. 125-143, 2013.

[25] V. Venkatesh, C. Speier, and M. G. Morris, "User acceptance enablers in individual decision making about technology: Toward an integrated model," *Decision Sciences,* vol. 33, pp. 297-316, 2002.

[26] C. Fornell and D. F. Larcker, "Structural equation models with unobservable variables and measurement error: Algebra and statistics," *Journal of marketing research,* pp. 382-388, 1981.

[27] R. M. O'brien, "A caution regarding rules of thumb for variance inflation factors," *Quality & Quantity,* vol. 41, pp. 673-690, 2007.

[28] P. M. Podsakoff, S. B. MacKenzie, J.-Y. Lee, and N. P. Podsakoff, "Common method biases in behavioral research: a critical review of the literature and recommended remedies," *Journal of applied psychology,* vol. 88, p. 879, 2003.

[29] C. C. Ragin and S. Davey, "fs/QCA [Computer Programme], version 2.5," *Irvine, CA: University of California,* 2014.

[30] C. C. Ragin, *Fuzzy-set social science*: University of Chicago Press, 2000.

[31] A. Ordanini, A. Parasuraman, and G. Rubera, "When the recipe is more important than the ingredients a Qualitative Comparative Analysis (QCA) of service innovation configurations," *Journal of Service Research,* vol. 17, pp. 134-149, 2014.

[32] C. Plewa, J. Ho, J. Conduit, and I. O. Karpen, "Reputation in higher education: A fuzzy set analysis of resource configurations," *Journal of Business Research,* 2016.

[33] C. C. Ragin, "Set relations in social research: Evaluating their consistency and coverage," *Political Analysis,* vol. 14, pp. 291-310, 2006.

[34] J. M. Mendel and M. M. Korjani, "Charles Ragin's fuzzy set qualitative comparative analysis (fsQCA) used for linguistic summarizations," *Information Sciences,* vol. 202, pp. 1-23, 2012.

[35] T. Busjahn, C. Schulte, B. Sharif, A. Begel, M. Hansen, R. Bednarik, *et al.*, "Eye tracking in computing education," in *Proceedings of the tenth annual conference on International computing education research*, 2014, pp. 3-10.