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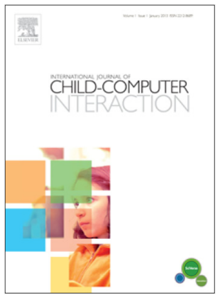

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How Do You Feel about Learning to Code? Investigating the Effect of Children's Attitudes towards Coding Using Eye-Tracking

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ABSTRACT

Computational thinking and coding for children are attracting increasing attention. There are several efforts around the globe to implement coding frameworks for children, and there is a need to develop an empirical knowledge base of methods and tools. One major problem for integrating study results into a common body of knowledge is the relatively limited measurements applied, and the relation of the widely used self-reporting methods with more objective measurements, such as biophysical ones. In this study, eye-tracking activity was used to measure children's learning and activity indicators. The goal of the study is to utilize eye-tracking to understand children's activity while they learn how to code and to investigate any potential association between children's attitudes and their gaze. In this contribution, we designed an experiment with 44 children (between 8 and 17 years old) who participated in a full-day construction-based coding activity. We recorded their gaze while they were working and captured their attitudes in relation to their learning, excitement and intention. The results showed a significant relation between children's attitudes (what they think about coding) and their gaze patterns (how they behaved during coding). Eye-tracking data provide initial insights into the behaviour of children, for example if children have difficulty in extracting information or fail to accomplish an expected task. Therefore, further studies need to be conducted to shed additional light on children's experience and learning during coding.

Keywords: children's attitudes; eye-tracking; coding; computational thinking; constructionism

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Abstract

Computational thinking and coding for children are attracting increasing attention. There are several efforts around the globe to implement coding frameworks for children, and there is a need to develop an empirical knowledge base of methods and tools. One major problem for integrating study results into a common body of knowledge is the relatively limited measurements applied, and the relation of the widely used self-reporting methods with more objective measurements, such as biophysical ones. In this study, eye-tracking activity was used to measure children's learning and activity indicators. The goal of the study is to utilize eye-tracking to understand children's activity while they learn how to code and to investigate any potential association between children's attitudes and their gaze. In this contribution, we designed an experiment with 44 children (between 8 and 17 years old) who participated in a full-day construction-based coding activity. We recorded their gaze while they were working and captured their attitudes in relation to their learning, excitement and intention. The results showed a significant relation between children's attitudes (what they think about coding) and their gaze patterns (how they behaved during coding). Eye-tracking data provide initial insights into the behaviour of children, for example if children have difficulty in extracting information or fail to accomplish an expected task. Therefore, further studies need to be conducted to shed additional light on children's experience and learning during coding.

Keywords: children's attitudes, eye-tracking, coding, computational thinking, constructionism

1. Introduction

Computational thinking and coding have become an integral part of the K-12 curriculum, as the Common Core Standards, the Computer Science Teachers Association and the International Society for Technology in Education standards have been widely applied. Coding is considered as a new literacy skill, and is integrated into the school curriculum in many countries, such as Estonia, Finland, Israel, Korea and the United Kingdom, to mention a few. Nowadays, governments seek to teach coding to all and to support young students in creative and problem-solving tasks [1]. Although there is a growing body of research in the area, there is still limited evidence on how to design successful coding experiences for children.

Given the large amount of software available and children-friendly programming environments such as Alice, Scratch, Greenfoot and Kodu, teaching coding has become a more intuitive and engaging experience for young students [2]. In addition, organizations such as "codecademy.com" and "code.org" have strengthened their offerings for children's coding experiences. Thus, while new technologies, innovative pedagogies, guidelines and resources in computing education exist, the challenging question arises of how to choose, design and implement the appropriate learning activity for children. Previous studies grounded in constructionist learning [3] have been successfully utilized both inside and outside the classroom. The results have shown increased interest in coding as well as in understanding the fundamental concepts of problem-solving [4, 5].

Combining computers with meaningful programmable objects, such as interactive robots, can provide a valuable coding-learning experience in a fun and playful manner [6]. Previous research described practices to motivate and engage children in coding through making and construction [7]. Robertson and Howells [8] argued that making a game was an authentic learning activity; their exploratory research based on qualitative data from sixth-grade students in Scotland showed that this activity provided motivation, engagement and enthusiasm for learning. Especially when making was combined with block-based programming environments such as Scratch, there was intensive use and improved understanding among the children of concepts including loops and variables [9]. Several studies indicated that coding tasks related to making, construction, game design and development have been found beneficial for children's attitudes towards coding and skills [10]. The current body of knowledge provides several insights into how to design and implement construction-based coding experiences for children; the existing studies have, however, focused on the experience, fun, enjoyment and engagement of the children (e.g.[4, 11]) as extracted from qualitative measures such as observations and interviews and/or quantitative measures including surveys (e.g. [12, 13]). Focusing on the use of other measures will help to better understand the way children learn how to code and give insights for the design of coding experiences.

Based on recent studies regarding coding and learning [14, 15], one important tool that has been used successfully to unveil the cognitive mechanisms underlying coding by adult programmers is eye-tracking. There are studies explaining expertise [16], collaboration quality [15], learning outcome [14] and task-based performance [17] using eye-tracking data. With children, the use of objective measures such as physiological (eye-tracking) data is important because they are generalizable (more than qualitative and subjective measures), real time and provide more reliable monitoring of users' actions. In contrast to other subjective measures, objective measures are independent of perceptual abilities. In addition, during data collection there is no need to interrupt the activity and ask for ratings. To the best of our knowledge, eye-tracking has not yet been used to investigate how children learn to code and any potential relation between children's attitudes and their gaze patterns.

In this contribution, we designed an experiment where children participated in a full-day construction-based coding activity. We recorded their gaze while they were coding and at the end of the day we captured their attitudes in relation to their perceived learning, excitement and intention during the coding activity. Thus, *in this contribution we investigate the relation between children's attitudes and gaze in coding tasks.*

The rest of paper is structured as follows: in the next section, the related work and background theories are outlined; the third section presents the methodology of the study employed in this article; and the fourth section documents the empirical results. The fifth section discusses the results derived, outlining the limitations and recommendations for future research, while the last section concludes the paper.

2. Related work and background theory

2.1. Learning coding through construction

Papert's [3] constructionism states that each child learns more deeply by actively building knowledge through experience. Children should discover knowledge rather than receiving it passively [18]. In the area of computing education, this is also endorsed by the ACM/IEEE Task Force on Computing Curricula [19]. The ACM/IEEE Task Force emphasizes the importance of the development and mastery of problem-solving skills integrated with real-world, group-based construction-learning activities. Motivated by Papert's constructionist approach, today's educational activities are embedding technology tools that provide learning experiences in educational contexts, which occur in environments that are not always learning oriented. In these types of dynamic learning activities, students are at the centre, taking control and engaging at their own will with a subject. Learning-by-doing, project-based learning, problem-based learning, inquiry-based learning and challenge-based learning are a few such instructional methods, occurring both inside and outside the classroom [20] and focused on learning tasks that promote computing education, computational thinking, design thinking, collaborative work and innovation.

Computer game design and development, modding and computational textiles/fabrication are among the most successfully applied practices which help students to develop coding skills and structure their own learning and thinking by getting involved in the process of coding [5, 21]. During such learning tasks, successful construction involves a complex process that fosters skills such as problem-solving, confronting "failures", and strategies to explore and decide possible solutions, as well as structure thoughts and actions [6]. Many tools, such as Cricket, Braitenberg Blocks and Arduino technologies, can provide opportunities to support fruitful learning experiences [22], while digital fabrication can provide Bildung (i.e. deep and sustained learning) [23]. Adams and Webster [24] reported the results from nine years of coding summer camps for middle and high school students. By analysing Scratch programs, they investigated the type of blocks students used and how aspects such as project types were related to the choice of these blocks. The literature suggests that children can successfully complete and learn by simple robot-based coding projects [25]. Robots have the capacity to enhance coding activities and allow children to engage in computational thinking using various programming concepts [26].

In a nutshell, construction-based activities create contextual and meaningful learning environments. As such, after designing a creative coding activity for children, we evaluate its effectiveness, with the primary goal being to understand how children learn coding and design those activities accordingly.

2.2. Students' attitudes and motivations towards coding and self-determination theory

Motivation appears as an important key in learning settings, not only for its positive results but also for its aspects of activation, intention [27] and promoting active learning [28]. Many studies throughout the years have shown that students' motivations have an influence on their performance, satisfaction and well-being [27, 29]. In general, the aim is to have positive attitudes towards something that is interesting and, consequently, interest and motivation relate to the individual's actions [30]. Concerning computing and computer science, students' attitudes and motivation are positive and high when projects and visual programming are involved, highlighting fun, commitment, enthusiasm and usefulness [4]. Katterfeld et al. [31] conducted a EduWear/TechKreativ workshop, where the students used a smart construction kit that revealed a feeling of empowerment and attitudes that increased students' ability to code. Giannakos and Jaccheri [32] found that children's positive attitudes regarding an activity's easiness and usefulness significantly affect engagement and their intention to participate. In particular, game-programming activities for children are motivating, support self-esteem and foster computational thinking [8]. According to Vos et al. [33], game programming reveals enthusiasm and motivation for learning and determination to accomplish a task.

Motivation is an important aspect of human behaviour. Self-determination theory (SDT) has been widely used to understand motivation within educational contexts [29] and is centred on the belief that people have needs that are the basis of self-motivation. There are three basic psychological needs that SDT supports: competence, autonomy and relatedness. According to SDT, opportunities to satisfy any of these three needs contribute to people being motivated. The type of motivation is related to one's goals and attitudes, leading to actions. In addition, SDT includes two different types of motivation: intrinsic and extrinsic. When someone is intrinsically motivated, he/she is engaged in an activity per se, for pleasure and satisfaction from its performance. On the other hand, extrinsic motivation refers to actions from outside sources leading to separable outcomes [27, 34]

In our approach, SDT presents a useful theoretical lens to represent children's experience with creative coding activities for learning. In line with the theory, our coding activity is designed to have active participants and to satisfy their needs for autonomy (with occasional support from the instructors), competence and relatedness, facilitating higher motivation in the children. We argue that this activity provides intrinsic motivation, a tendency towards learning and creativity leading to performance, as suggested by Vos et al. [33]. In our study, we provide a creative coding activity that encourages children to make decisions, act independently and work collaboratively with their peers. Hence, autonomy and competence are reinforced. Relatedness involves the development of satisfaction in the social context; therefore, we focus on a pleasurable attitude: excitement, in our case.

Based on the theory and the importance of positive attitudes and motivations in coding activities for children, we hypothesize that our coding activity supports the aforementioned three basic psychological needs [29] so children show high intention, performance expectancy and excitement during and after the coding sessions. On a given learning activity, motives are important to cognitive learning; the level of motivation influences focus and level of effort. More specifically, it could be argued that by having the required motivations, children gain the ability and energy required to sustain positive attitudes towards coding. Positive attitudes facilitate cognitive processing and improve cognitive and affective outcomes. Therefore, this study investigates the impact of our coding activity on students' attitudes (i.e. perceived leaning, excitement and intention to participate in a similar activity) and examines the connection with objectively measured variables illustrating cognition (in our study, eye-tracking data).

2.3. Eye movements in cognitive process of coding

One of the objective technologies for studying cognitive processes in a deep and subjective way is eye-tracking. Eye movements are strongly related to cognition [35, 36] and have been used to investigate learning [37], reading [38] and problem-solving [39]. In addition, several studies use eye-movement data to examine adult programmers' visual attention and explore coding, program comprehension [40, 41] and debugging [42]. The use of different visual attention measures, such as fixations, saccades or time spent on parts of the screen called Areas of Interest (AOI), can give insights to understand complex cognition activities. Romero et al. [43] compared the use of different program representation modalities (propositional and diagrammatic) in an expert versus novice debugging study, where experts had a more balanced shift of focus among the different modalities than did the novices. Sharif et al. [44]

emphasized the importance of code scan time in a debugging task and concluded that experts perform better and have a shorter code scan time. Hejmady and Narayanan [45], comparing the gaze shift between different AOIs in a debugging intergraded development environment (IDE), showed that good debuggers were switching between code, expression evaluation and the variable window, rather than code, control structure and the data structure window. In another study, Aschwanden and Crosby [40] defined each line of the code as an AOI and detected how these lines were perceived. Pietinen et al. [46] assessed the quality of collaboration by measuring joint visual attention in a co-located pair programming setup, using the number of overlapping fixations. Bednarik and Tukiainen [41] examined the coordination of different program representations in a program-understanding task. Experts concentrated more on the source code rather than looking at the other representations.

Though many studies have used cognitive neuroscience techniques such as eye tracking [47] to examine the role of eye movements in adults' coding cognition and behaviour, there is a lack of studies using them to assist our understanding of children's cognitive processes in coding activities [48]. Hence, we used eye-tracking to capture children's allocated attention to different sources of information during our creative coding experience.

2.4 Cognitive load theory

Cognitive load theory (CLT) implies that people have a limited working memory and that the amount of information they can process cannot therefore exceed the limit at which they are overwhelmed [49]. There are three types of cognitive load: intrinsic, extraneous and germane. Intrinsic load refers to the task and its core characteristics that must be processed. Extraneous load is based on the form of representation and the techniques used in the instructional design. Germane load involves information consolidation and refers to schema production for permanent knowledge.

The intrinsic load effort in our case of a designed coding activity is represented by the performance of the task and its own load due to complexity. The use of the Scratch programming environment for the completion of the activity and the instructional details relate to the extraneous load. Finally, the germane load consists in the effort and processes from the task which are directed to the relevant learning [50].

Cognitive load can have an influence on visual attention and behaviour. The eye's different fixations show the distribution of attention [51], while the cognitive process from graphic and textual visual materials is connected with fixation behaviour (locus, duration and sequence) [52]. In particular, eye-movement measures such as number of fixations, fixation duration, duration time and different scanning paths can reveal important aspects of the learners' cognitive process [36]. High fixation duration depicts high cognitive activity [53] and fewer saccades can be related to less cognitive effort in terms of task performance [47]. In a study about maths and physics problems, participants had longer fixations in the more complicated parts of the problem [54].

In this study, in line with CLT, the designed coding activity has an overall cognitive load that subsequently influences children's cognitive process and can become overwhelming. We assume that the working memory of children, and especially of novices to coding, can quickly be overloaded by task complexity, and that this will lead to an inefficient learning environment. Thus, we attempt to use an eye-tracking technique as a proxy for cognition [47] to investigate children's cognitive processes in learning [55] during our creative coding activity. The eye measures will show the cognitive overload and we examine their relationship to children's attitudes regarding the activity.

2.5 Goal of the study

Coding activities based on constructionist learning enhance learners' motivations and help them to incorporate knowledge, attitudes and behaviour to achieve effective learning and performance [56]. In addition, there is a need to have the proper instructions and guidance to support self-efficacy for learning [57]. Nevertheless, the cognitive load of these activities can be high and the increased task complexity can become overwhelming. Therefore, to create an effective and efficient learning environment, motivational effects should be considered [57, 58].

Based on previous research and the theoretical grounding, we assume that cognitive load is related to children's attitudes and motivation in creative coding activities. In particular, we predict that more highly motivated children with more positive attitudes have better management and a lower cognitive load. The present study fills the gap of using eye movements as an objective measurement to depict children's cognitive processes while coding and examine how they are related to their attitudes.

The aim of this study is summarized by the following research question:

- *What is the relation between children's attitudes and gaze in coding activities?*

3. Methodology

3.1. The coding activity

Based on the constructionist approach and its main principle, learning by doing [59], as well as previous efforts [32], we conducted a coding workshop at the Norwegian University of Science and Technology, in Trondheim, Norway. Our coding workshops are out-of-school activities, in which children from 8 to 17 years old interact with digital robots, using Scratch for Arduino (S4A), and then code their own game using the Scratch programming language. At each workshop the children work in pairs or triads and the activity lasts for approximately four hours. Five assistants with previous experience in similar activities are responsible for instruction and the procedure for the workshops.

The workshop consists of two main parts, interaction with the robots and creating games with Scratch; Figure 1 depicts the flow of these two parts.

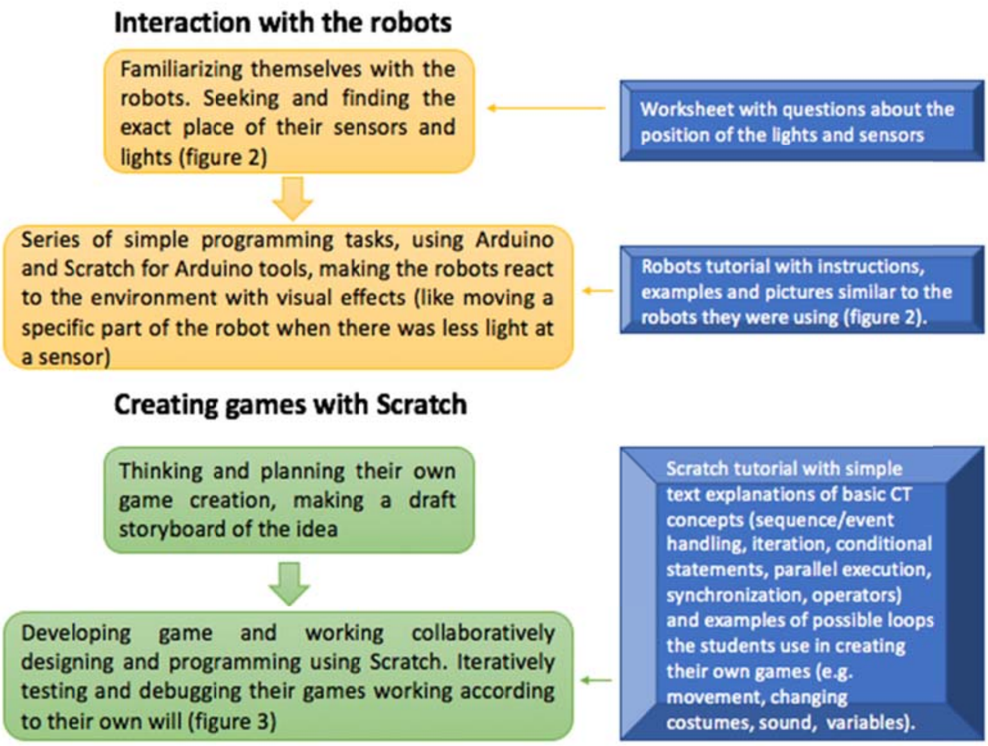

Figure 1: Description of the two activities in the workshop

Interaction with the robots: During the first part of the coding activity, the children interact with digital robots built by an artist using recycled materials, mainly from computer parts. First, as the children enter the room and are welcomed by the assistants, they sit in teams next to one robot. The assistants give a brief presentation of the workshop's activities and ask each of the children to pay attention to a worksheet placed on the desk next to them. The goal is to familiarize themselves with the robots by filling in simple questions regarding the exact place and number of the sensors and lights on the robots. Then, the children use a paper tutorial with instructions (Figure 2) for how to make the robots react to the physical environment with visual effects using simple loops of Scratch for Arduino (e.g. to make the tongue of the snake robot move when there is less light at a sensor). The teams work collaboratively and independently to complete this task (Figure 3 left). The duration of the first part varies from 45 to 90 minutes. When all the teams have finished, the children have a break before the next section begins. This part of the workshop offers a smooth start to coding, including tangible objects. The interaction with digital robots provides a better understanding of STEM subjects by showing the connection with the physical world, helping the children to cope with difficult problems [60]. The children are introduced to coding by playfully interacting with the robots while they get motivation and inspiration.

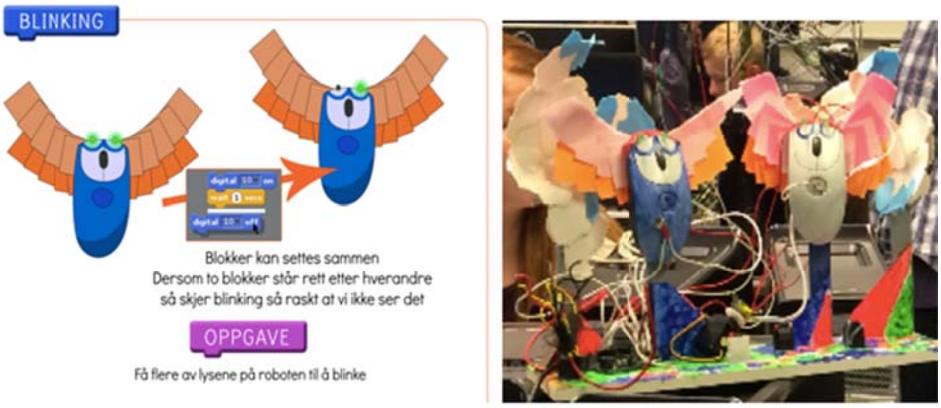

Figure 2: Example of the robots' tutorial on how children interact with robots

Creating games with Scratch: This section is the main activity of the workshop and lasts approximately three hours, without the presence of the robots. The goal is to successfully develop a simple game, coding in Scratch. To achieve this goal, the assistants give another paper tutorial with examples of all the basic Computer Science (CS) concepts and possible loops they should use to complete their own game. The assistants advise the children how to manage the process of game development, working collaboratively. First, they should think about and decide the story for their game and then create a draft storyboard. When they finish that, they start coding using Scratch. The children can ask for support from the assistants whenever they need it throughout the activity. The assistants offer their guidance to the teams, helping them to complete their games and introducing even more complex CS concepts when needed. Finally, after the completion of the games, the children reflect and play each other's games (Figure 3 right).

Figure 3: Children interacting with the robot (left) and example of developed game (right).

3.2. Sampling

We conducted the study at a dedicated lab space at the Norwegian University of Science and Technology, in Trondheim, Norway. Specifically, the study lasted two weeks during Autumn 2016, with 44 children from the eighth to twelfth grades (aged 8–17 years old), 12 girls (mean age: 12.64, standard deviation (SD): 2.838) and 32 boys (mean age: 12.35, SD: 2.773). Five workshops were held in total, all following the same process for the coding activity, addressed to novices in coding. Some of the participants in the sample (13–17 years old) were recruited from the local schools who had applied to take part in our activity (called Kodeløypa in Norwegian, meaning the path to coding). The other set of participants (8–12 years old) were youngsters who attend local coding clubs (Kodeklubben: https://trondheim.kodeklubben.no/)

as an after-school activity. The children volunteered their participation in the eye-tracking study and the legal guardians provided a written informed consent form for their child, giving permission for the data collection. In our sample of 44 children in total, 27 children had attended 0–1 workshops about coding before, 15 children 2–5 workshops, and only 2 children more than 5 workshops. In addition, among the children aged 13–17 years, 18 out of 29 participants had chosen less than 3 (mean: 3.06, SD: 1.404) on a seven-point Likert scale measuring their own experience in coding, and only 4 chose more than 5, while none of them chose more than 6.

3.3. Measures

As mentioned before, this study is one of the few so far utilizing children's gaze. We recorded children's gaze while they were coding using the Scratch environment during both parts of the activity. The eye-tracking data was collected using four SMI and one Tobii eye-tracking glasses. The sampling rate for all the eye-tracking glasses was set to be 30 Hz for the binocular eye-tracking. The average accuracy for both SMI and Tobii glasses was 0.5 degrees at a distance of 40 Centimetres.

Many measures have been used to examine cognition. Fixations calculate the time spent on a specific location, reflecting attention and processing time, while saccades represent the shifts between fixations [47].
Based on the literature and prior studies [61], we selected the following gaze measures:

1. Fixation duration: High fixation duration depicts that the participant is having difficulty in extracting information [52]. The authors used a mental rotation task, with 0, 120 and 180 degrees, to study the relation between problem difficulty and gaze patterns. The results showed that with an increase in the rotation angle (increasing difficulty), the fixation duration at the centre of the figure and the arms of the structures increased [52].
2. Saccade amplitude: longer saccades show meaningful transitions in terms of attention [62]. In a web search task, the authors used a set of different tasks on a webpage, so that the participants had to look for particular information to complete the tasks. The results showed that pre-planned eye movements were accompanied by longer saccades [62].
3. Change in saccade direction: the angle between two lines, if more than 90 degrees, reflects a change of plans, revision or a failed expectation/hypothesis/anticipation [63]. In a usability study, the authors found that the change in saccade direction often depicted the behaviour of not finding something which the participants anticipated to find at certain places [63]. This can be translated, in terms of programming behaviour, as having a certain hypothesis and a failed verification.

At the end of the activity, the children completed a paper-based survey. The surveys gathered feedback on the children's attitudes regarding the coding activity. In Table 1, we summarize the operational definitions of these factors, the items and their respective bibliographical sources. The children were asked to rate their experience with the coding activity regarding their learning, excitement and intention. In all measures, a five-point Likert scale was applied using smiley faces [64] (figure 4) . Table 1 clearly exhibits the questions put to the children.

Table 1: The attitudinal factors and their respective questions, operational definitions and sources

Factors	**Operational Definitions**	**Item**	**Source**
Learning	Perceived learning (we refer to this as learning in this paper) is the degree to which children indicate their performance.	Please indicate if you learned new things during the coding activity (Not at all – Very much)	[65]
Excitement	Excitement is the degree to which children indicate their excitement for the coding activity	Please indicate how you feel about participating in the coding activity (Dull – Exciting)	[66]
Intention	Intention is the degree of children's willingness to participate in a similar activity.	Please indicate how much you want to attend similar coding activities in the future (Not at all – Very much)	[32]

Figure 4: Example of emoticons used in the survey to measure children's attitudes (Adopted from Hall et al. [64])

3.4. Data analysis

As mentioned above, 44 children were involved in this study. To test our research question the data were separated into three groups, each for one of the three attitudinal factors: learning, intention and excitement. The first group consisted of children who rated the respective attitude 3 or less (relatively low), the second of children who rated it 4 (relatively medium) and the third of children who rated it 5 (relatively high). First, we used Levene's test to examine the homogeneity of variance and the Shapiro–Wilk test to evaluate the normality criterion [67, 68] in order to use ANOVA analysis (see the table in the appendix). Afterwards, 9 separate one-way independent ANOVA tests were conducted to examine our research question. For all tests we did not assume equality of variance across groups. The p-values for the main and post-hoc tests are computed in accordance with the Bonferroni correction for the repeated tests. Also, since we are not assuming the variance across groups to be equal, the F-values are adjusted according to the Welch correction for the partial degrees of freedom.

4. Research findings

Children expressed high learning and excitement (4.7/5 and 4.6/5, respectively) for the coding activity. Additionally, they expressed slightly lower intention (4.5/5). High levels of these attitudes indicate positive views concerning their learning performance and beliefs regarding their future engagement with coding activities. The descriptive statistics about children's attitudes and eye-tracking measures are summarized in Table 2.

Table 2: Descriptive statistics of the study

Variable	Median	Mean	SD	Min	Max
Learning (scale 1–5)	5.0	4.7	0.82	1	5
Intention (scale 1–5)	5.0	4.5	0.76	2	5
Excitement (scale 1–5)	5.0	4.6	0.65	3	5
Fixation duration (milliseconds)	268.46	270.8	90.62	110.0	579.9
Saccade direction change (milliseconds)	36.70	38.76	16.06	12.06	92.47
Saccade amplitude (degrees)	177.24	186.78	61.07	92.81	356.98

As mentioned before, to examine our research question one-way ANOVA was used, and the three independent variables (learning, excitement, intention) and the three dependent variables (fixation duration, saccade direction change, saccade amplitude) were included. As can be seen from the outcome data in Table 3, children's learning, excitement and intention exhibited a highly significant relation with their gaze patterns, supporting our research assumption. The results of the 9 separate one-way independent ANOVAs (without assuming equal variances across groups) are summarized in Table 3.

Table 3: Testing the effect of children's attitudes in their eye-tracking patterns during coding

Variables	**Learning**				**Intention**				**Excitement**			
	Mean (SD)			**F-Value**	**Mean (SD)**			**F-Value**	**Mean (SD)**			**F-Value**
	3 or less	**4**	**5**		**3 or less**	**4**	**5**		**3 or less**	**4**	**5**	
Fixation duration	488 (79)	328 (43)	244 (65)	16.06**	389 (52)	293 (116)	243 (66)	14.41**	424 (112)	287 (100)	246 (63)	4.83*
Saccade direction change	76.6 (20)	44.6 (6.3)	34.9 (12.1)	4.47*	58.2 (15.8)	45.9 (18.1)	32.9 (11.5)	6.94*	63 (23)	46 (16)	33 (11)	5.13*
Saccade amplitude	115 (14)	143 (38)	198 (59)	19.35***	123 (17)	177 (60)	200 (60)	16.46***	141 (26)	168 (59)	198 (62)	5.32*

Significance level: ***p < .001; **p < .01; *p < .05

We observe the following relations between the attitudes (learning, intention and excitement) and the gaze variables (fixation duration, saccade amplitude and saccade direction change).

For gaze and perceived learning, we observe a significant relation between all the gaze variables and learning (Figure 5). In particular, the children who reported higher learning had lower fixation duration ($F[2, 4.37] = 16.06$, $p = .009$), lower saccade direction change ($F[2, 4.47] = 4.47$, $p = .03$) and higher saccade amplitude ($F[2, 8.32] = 19.35$, $p = .0007$) than those who reported lower learning. Furthermore, pairwise comparisons show that the average fixation duration decreases significantly with an increase in perceived learning (3 vs. 4 F[1,2.73] = 10.33, p = .05; 3 vs. 5 F[1,2.25] = 26.74, p = .02; 4 vs. 5 F[1,6.85] = 14.19, p = .007). Considering the average change in the saccade direction, it does not differ significantly from 3 to 5 (F[1,2.12] = 12.66, p = .09) or 3 to 4 (F[1,2.24] = 7.70, p = .06), but it is significantly higher for the children who reported the perceived learning as 4 than for those who reported the perceived learning as 5 (F[1,6.85] = 14.19, p = .03). Finally, concerning the average saccadic amplitude, it does not differ significantly from the 3 to 4 rating (F[1,5,45] = 2.16, p = .19), but it is significantly higher for 5 than for the other two ratings (3 vs. 5 F[1,10.71] = 41.70, p = . 0005; 4 vs. 5 F[1,7.60] = 6.97, p = .02).

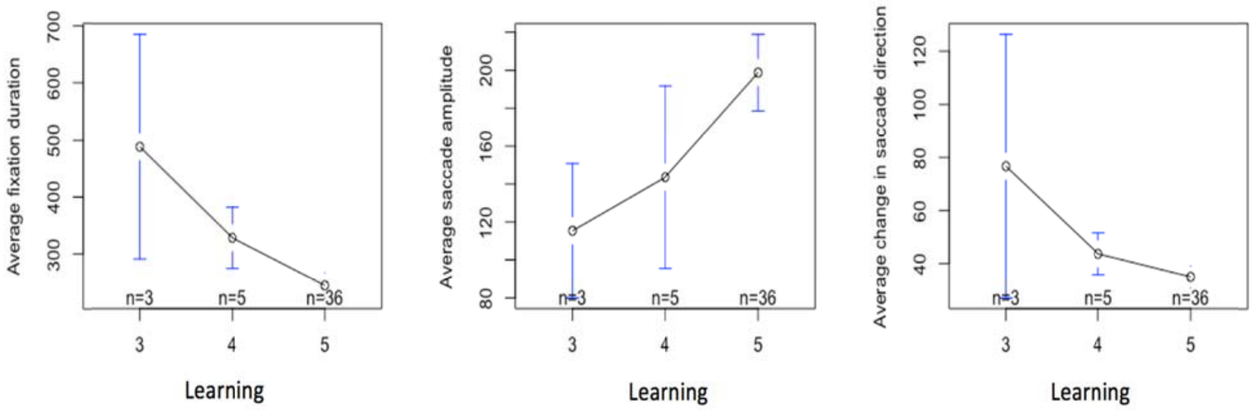

Figure 5: The influence of learning on children's gaze during the coding activity. The blue bars are the 95% confidence intervals.

For gaze and intention, we observe a significant relation between all the gaze variables and the intention to program (Figure 6). In particular, the children who reported higher intention to code had lower fixation duration (F[2, 10.40] = 14.41, p = .001), lower saccade direction change (F[2, 8.81] = 6.94, p = .01) and higher saccade amplitude (F[2, 18.09] = 16.46, p = .00008) than those who reported lower intention. Pairwise comparisons show that the fixation durations do not differ significantly between levels 4 and 5 (F[1,11.11] = 1.65, p = 0.22), but do decrease significantly for levels 4 (F[1,12.97] = 4.88, p = .04) and 5 (F[1,6.47] = 30.46, p = .001) as compared to level 3. When we conducted the pairwise comparisons for the saccade direction change, we did not observe any difference between levels 3 and 4 (F[1, 9.19] = 1.82, p = .20), but there is a significant decrease in the direction change for level 5 when compared against levels 3 (F[1,4.75] = 11.72, p = .02) and 4 (F[1,11.61] = 4.54, p = .05). Finally, considering the pairwise comparisons for saccadic amplitude, it increases significantly between levels 3 and 4 (F[1,11.60] = 6.94, p = .02) and 3 and 5 (F[1,22.85] = 32.89, p = .0001); however, we did not observe any significant differences between levels 4 and 5 (F[1,15.68] = 1.12, p = .30)

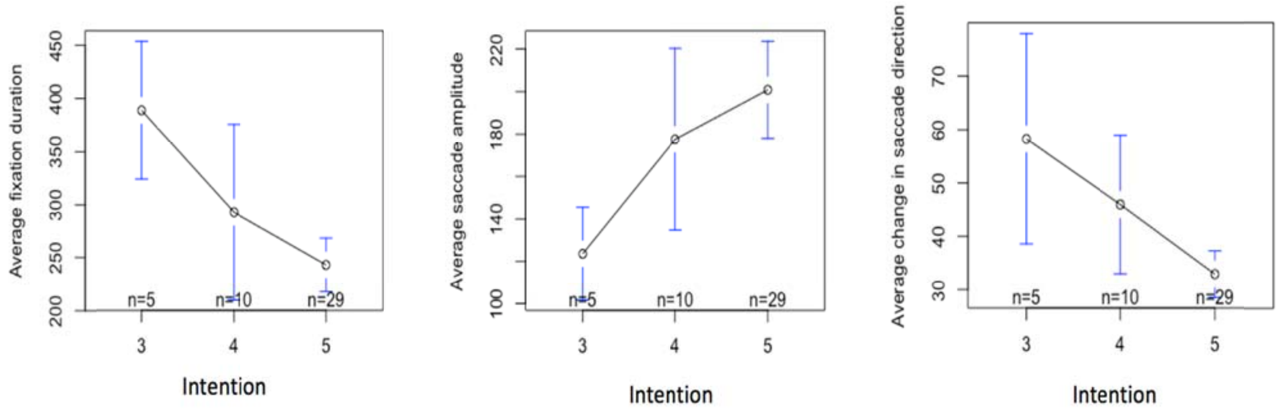

Figure 6: The influence of intention on children's gaze during the coding activity. The blue bars are the 95% confidence intervals.

For gaze and excitement, we observe a significant relation between all the gaze variables and excitement during the coding task (Figure 7). In particular, the children who reported higher excitement had lower fixation duration (F[2, 6.48] = 4.83, p = .05), lower saccade direction change (F[2, 6.50] = 5.13, p = .04) and higher saccade amplitude (F[2, 11.39] = 5.32, p = .02) than those who reported lower excitement during the coding task. Pairwise comparisons show that the fixation durations are not different for levels 3 and 4 (F[1, 5.28] = 4.40, p = .08) and 4 and 5 (F[1, 9.92] = 1.35, p = .27), but fixation durations are significantly lower for level 5 than those for level 3 (F[1, 3.25] = 9.73, p = .04). The saccadic direction change is significantly lower for level 5 than for level 4 (F[1, 10.62] = 5.18, p = .04) and we do not observe any other differences between levels 3 and 4 (F[1, 4.32] = 1,95, p = .22) or levels 3 and 5 (F[1, 3.20] = 6.86, p = .07). Finally, the saccade amplitudes are not significantly different between levels 3 and 4 (F[1, 10.96] = 1.36, p = .26) and levels 4 and 5 (F[1, 13.52] = 1.62, p = .22); however, saccade amplitudes are significantly higher for level 5 than those for level 3 (F[1,8.67] = 11.02, p = .009).

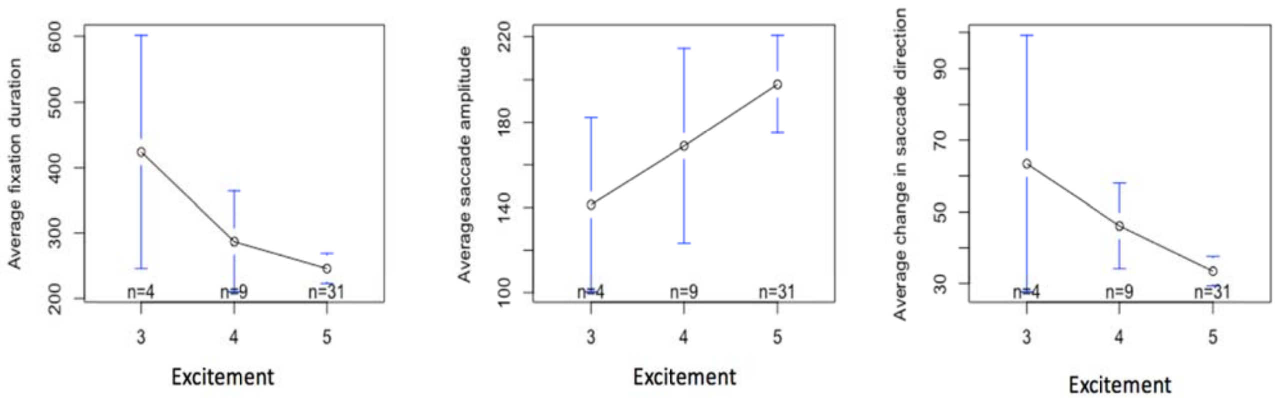

Figure 7: The influence of excitement on children's gaze during the coding activity. The blue bars are the 95% confidence intervals.

5. Discussion and conclusions

This study is the first attempt to investigate potential relations between children's attitudes and their gaze during coding activities. For that purpose, in addition to the attitudinal survey (learning, excitement and intention), we collected eye-tracking data from children aged 8 to 17 years during our construction-based coding activity. The results showed a significant relation between children’s attitudes and their gaze patterns. There are many studies [31, 69] focusing on how children interact with digital fabrication and construct games using a programming environment. In our study, we used robots and the Scratch tool.

Change in children’s attitudes through game making and engagement with digital media is as important as motivation to learning, since it represents a long-term profit and can be expressed as a later career interest [70]. Our study suggests that gaze patterns and attitudes can be correlated. The three different gaze measures used represent children’s difficulties in extracting information during a coding activity (fixation duration), the number of trials needed to learn something during coding (saccade direction change) and children’s goals and expectations during coding (saccade amplitude). As was expected, children who had fewer difficulties and could handle the cognitive load better had higher scores in their attitudes. When the instructional conditions enhance their motivations, offer the proper way to manage the tasks’ overwhelming conditions and maintain children’s focus, there are positive results from their experience. This finding also highlights the importance of proper assistance from the instructor and the materials/tools in coding activities.

In particular, high fixation duration corresponds to children’s difficulty in extracting the information needed to accomplish a task. Lower fixation duration depicts the fact that the user (the child in our case) is experiencing less difficulty in extracting information from the stimulus [52]. We found that children who report lower learning have higher fixation duration. That can be attributed to the fact that they possibly put a lot of effort into understanding and choosing the appropriate tools and/or commands in accomplishing the task of creating their game and controlling the robots, resulting in a higher cognitive load. On the contrary, children who believe that they learn more have lower fixation duration, so less of a cognitive load, assuming that they were frequently checking different commands until they found the preferred one and also taking quicker decisions while coding [71]. High saccade amplitude or long saccades show that the transitions in attention are more meaningful than transitions with shorter saccades [63]. In other words, longer saccades depict more of a hypothesis-verification kind of gaze behaviour, and are also indicative of multiple trials to learn a particular topic. This is in accordance with previous studies where young children who are novices at coding rarely try to debug their program and when they do so, find great difficulty in solving issues with a program that is not properly executed [72]. Perkins et al. [73] describe different categories of children while solving a problem: “stoppers”, who have no intention of trying different problem-solving methods; “movers”, the ones who are willing to try different ways; and “extreme solvers”, who try different ways without carefully thinking about them.

One interesting result is that the differences in children’s gaze were higher for intention and learning than for excitement. This is possibly related to the fact that excitement derives from intrinsic motivation, driven by interest and enjoyment in the coding activity, and exists within the individual. On the other hand, intention and learning after an educational activity are attitudes closer to the learning tasks than the individual, so are more complicated to effect. Moreover, in terms of the reported excitement, the children with higher levels of excitement had the same characteristics as those who reported high learning. It is not a surprising result that when children experience difficulties in coding they feel less excited, as fun and enjoyment derive from successfully completing functional projects that also give a positive overall experience [12, 13].

Expectation confirmation theory [74] asserts that continuance intention is mainly determined by satisfaction with prior experience. To understand this, one has to recall that satisfaction is synonymous with affect (i.e. a positive or negative feeling), and further that affect (as attitude or satisfaction) in prior learning studies is found to be an important predictor of intentions and decisions concerning the use of learning tools and practices (e.g. [75]). Enjoyment and satisfaction affect children's intention to participate in similar activities in the future [76, 77]. In our case, children with higher excitement had lower saccade direction change. Likewise, those who reported higher intention had lower saccade direction change. This type of similarity in children's gaze pattern represents that the ones who reported a high level of excitement have also high intention, in accordance with expectation confirmation theory. In the literature, a high amount of saccade direction change depicts sudden changes in short-term goals or expectations [62].

During our study the researchers also collected some notes from observations and assistants' comments, adding some interesting qualitative findings that illustrate children's behaviour during the coding activity. In general, the majority of the children expressed their satisfaction with the activity, and also mentioned a nice atmosphere. Their comments included sentences such as "it is so funny I can make the tail move" or "I like that I am with friends all learning how to code". Enthusiasm was more obvious in younger children's teams, and their willingness to code was expressed even with quarrelling. In conjunction with other studies [11], it was clear among the teams that girls were focusing more on the drawing and the story. In addition, some teams were working more methodically, following the tutorials, while others were working more independently, but asking more frequently for help from the assistants.

5.1. Practical and theoretical implications

Our eye-tracking data analysis in a coding activity with children is a first step towards using eye-tracking to unveil children's experience in the coding process. Several studies have successfully shown a clear relation between gaze patterns and performance, learning strategy and other personality factors [14, 17] That makes our approach an important contribution in eye-tracking, child–computer interaction and computer science education communities.

Scholars, educators and practitioners should pay particular attention to children's attitudes, since they heavily influence their experience. A coding activity should not overlook children's excitement, fostering enjoyment and confidence (i.e. high perceived learning). Instructors should focus on presenting support at the appropriate time, to reduce the cognitive overload and help children achieve a fruitful coding experience.

Our study verifies and extends the work of Abeysekera and Dawson [78], who suggest combining CLT and SDT to create a theoretical model for the flipped classroom, which investigates the increase of motivation to better manage cognitive load. This study confirms the fact that motivated children with positive attitudes have better management of cognitive load, as was represented by their eye movements. Indeed, we examine the two theories in the different context of children's coding activity, providing empirical support. Moreover, including eye-tracking data in the design of our study expands the scope of the theories providing evidence from the use of an objective data-collection method. In addition, other studies using eye-tracking have mainly focused on multimedia learning theories directly related to vision [55, 79], but from our perspective, including SDT shows evidence that goes deeper into users' behaviour.

Our findings demonstrate that the way children perceive the cognitive load from the learning process is related to their attitudes. According to CLT's relation to learning, instruction should align with human cognitive architecture [50] as well as enhance the motivation of learners [58]. Motivation and positive consequences are related [27], so self-determined children feeling excitement when performing a task may have a higher possibility of repeating the task in the future. Supportive teaching methods should provide guidance to help children distinguish the relevant factors to complete the task, preventing them from becoming overwhelmed by irrelevant information and actions. For example, they should help them focus on specific parts of the screen to find the respective code segments, split the code into meaningful chunks and trace the coding process in an effective way. In parallel, during learning activities instructors should foster students' self-confidence in their ability to complete the task successfully and ensure a pleasant and motivated environment. Moreover, there is a need for properly designed tools to help reduce cognitive overload. The design of the aesthetics of the visual coding tool is important to give a pleasant sense for children's use, but it should also help them indicate in a clear way the input and output values while coding. One example could be the clear representation of code segments and less complexity in scripting (e.g. fewer sprites and stacks of code). Another thought might be the design of dynamic coding tools that could be further developed according to children's progress in the coding task, such as starting with fewer code segments and gradually providing more advanced coding possibilities in relation to progress. In short, during coding activities for children it is important to take the motivational and cognitive effects equally into consideration in order to support effective and efficient learning environments.

5.2. Limitations

The present study is one of the first to offer insights into the relation of gaze patterns and children's attitudes. Nevertheless, some limitations should be mentioned. First, we faced a difficulty in capturing the gaze of 8–12–year-old children, since they were constantly moving their heads during the workshop and the glasses were sometimes irritating, so they had to remove them for some of the time. Their young age and the fact that most of the time they were very excited during the activity and spent a lot of time talking to each other, sharing their experience, made it very difficult to have good-quality data. The data can be corrupted due to many reasons. For instance, some of the participants removed the glasses and wore them again without the experimenters noticing, which resulted in some calibration errors, and thus data from those participants, after we noticed the lack of calibration, were removed from the analysis. Another reason for removing part (or the whole) of the data from a participant is that when they looked directly into a light source, the automatic calibration took a few seconds to recover from the sudden change in luminance. Nevertheless, we could use 75% of the data collected. Lost data was mainly from gaze in places that were not relevant for the experiment; for any other reason data were few and very carefully removed in order not to affect the analysis and provide more valid remained data. In their study, Nevalainen and Sajaniemi [80] reported invalid data of less than 10% of all the collected eye-tracking data from three different tracking devices, while Pernilla and Zhai [81] removed data from three out of fifteen participants in their eye-tracking study. Second, the duration of the activity was not strictly equal every day: children were recruited from the local coding clubs (Kodeklubben: https://trondheim.kodeklubben.no/) and schools, so we had to adjust the activity and sometimes streamline the schedule. However, this adjustment turned out to be constructive, since the children managed to complete sufficient of the workshops' activities and it did not become overwhelming for the majority of them, so that they did not report boredom or decrease their attention. Our coding activity is designed for children who have no previous experience in coding, so everyone can attend. Nevertheless, we cannot know the actual level of children's coding skills and exactly how much they have been exposed to coding before at school and/or in home activities. In addition, at the time of our study the local clubs were just starting their academic year, so the younger participants (8–12 years old) had not had many courses. Another limitation of the study was the lack of structured qualitative data (e.g. observations and interviews). The collection of that type of data could provide valuable insights into our findings and shed some light on children's behaviour during construction-based coding activities. Therefore, qualitative data collection could be taken into account in future studies. Finally, our study took place in Norway and participants voluntarily participated, so other sampling methods and demographic variables (i.e. educational level, family status) might have a contingent effect on children's attitudes.

5.3. Future work

For future work an opportunity will be to collect and analyse eye-tracking data in relation to gender differences. In her study, Robertson [11] identifies differences in game products for boys and girls and in order to investigate these differences she examined the time spent in different types of making process. Eye-tracking measures could be a promising approach to explaining gender differences from another perspective. Furthermore, in future studies attention should be paid to investigating the learning outcomes in terms of learning-specific computer science concepts and how they are related to different gaze patterns. In addition, the study could be extended to compare the results from children's gaze patterns in other attitudes as well as comparing alternative coding learning environments.

5.4. Conclusion

The present study can be regarded as a first step towards the use of eye-tracking method to examine children's learning behavior in creative coding activities. Based on the constructionist approach we conducted a coding workshop in which children were coding interactive robots and games using the Scratch programming environment. With the goal to examine how children's attitudes and gaze are related, we collected their attitudes via surveys and recorded their gaze via eye trackers. The examined attitudes include *perceived learning, excitement* and *intention*, all measured in five-point Likert scale using smiley faces. For the gaze we used three different measures connected to cognition, these are: *fixation duration* (showing difficulties in extracting information), *saccade direction change* (efforts needed to learn something) and *saccade direction change* (goals and expectations during the activity).

To support our assumption, that cognitive load relates with children's attitudes and motivation, our approach is grounded on self-determination theory and cognitive load theory. The results demonstrate a significant relation between attitudes and children's gaze patterns during the coding activity. More specific, children who indicated better management of cognitive load, expressed higher scores in their attitudes. Findings also suggest that children with higher reported excitement and learning had the same characteristics. This study demonstrates that the use of eye-tracking provides information about children's approach on handling coding tasks; that can be especially beneficial for the design of successful coding activities for children. Appropriate teaching methods and tools should focus on providing support avoiding unnecessary disruptions that can become overwhelming.

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References

[1] P. Hubwieser, M. Armoni, M.N. Giannakos, R.T. Mittermeir, Perspectives and visions of computer science education in primary and secondary (K-12) Schools, *ACM Transactions on Computing Education (TOCE)*, **14** (2014) 7.
[2] M.N. Giannakos, Reviewing the Affordances of Tangible Programming Languages: Implications for Design and Practice, *IDC workshop Every Child a Coder? Research Challenges for a 5-18 Programming Curriculum.*, (2015).
[3] S. Papert, Mindstorms: Children, computers, and powerful ideas, Basic Books, Inc., 1980.
[4] J.-M. Sáez-López, M. Román-González, 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*, **97** (2016) 129-141.
[5] S. Papavlasopoulou, M.N. Giannakos, L. Jaccheri, Empirical studies on the Maker Movement, a promising approach to learning: A literature review, *Entertainment Computing*, **18** (2017) 57-78.
[6] M.U. Bers, L. Flannery, E.R. Kazakoff, A. Sullivan, Computational thinking and tinkering: Exploration of an early childhood robotics curriculum, *Computers & Education*, **72** (2014) 145-157.
[7] J. Denner, S. Bean, J. Martinez, The girl game company: Engaging latina girls in information technology, *Afterschool Matters*, **8** (2009) 26-35.
[8] J. Robertson, C. Howells, Computer game design: Opportunities for successful learning, *Computers & Education*, **50** (2008) 559-578.
[9] J.H. Maloney, K. Peppler, Y. Kafai, M. Resnick, N. Rusk, Programming by choice: urban youth learning programming with scratch, ACM, Proceedings of the 39th SIGCSE technical symposium on Computer science education 2008.
[10] J. Denner, What Predicts Middle School Girls' Interest in Computing?, *International Journal of Gender, Science and Technology*, **3** (2011).
[11] J. Robertson, Making games in the classroom: Benefits and gender concerns, *Computers & Education*, **59** (2012) 385-398.
[12] K. Qiu, L. Buechley, E. Baafi, W. Dubow, A curriculum for teaching computer science through computational textiles, in: Proceedings of the 12th International Conference on Interaction Design and Children, ACM, 2013, pp. 20-27.
[13] K.A. Searle, D.A. Fields, D.A. Lui, 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, ACM, 2014, pp. 75-82.

[14] P. Jermann, M.-A. Nüssli, Effects of sharing text selections on gaze cross-recurrence and interaction quality in a pair programming task, in: Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work, ACM, 2012, pp. 1125-1134.
[15] K. Sharma, D. Caballero, H. Verma, P. Jermann, P. Dillenbourg, Looking AT versus looking THROUGH: A dual eye-tracking study in MOOC context, in: Exploring the material conditions of learning: opportunities and challenges for CSCL," the Proceedings of the Computer Supported Collaborative Learning (CSCL) Conference, 2015, pp. 260-267.
[16] P. Jermann, M.-A. Nüssli, W. Li, Using dual eye-tracking to unveil coordination and expertise in collaborative Tetris, in: Proceedings of the 24th BCS Interaction Specialist Group Conference, British Computer Society, 2010, pp. 36-44.
[17] M.-A. Nüssli, P. Jermann, M. Sangin, P. Dillenbourg, Collaboration and abstract representations: towards predictive models based on raw speech and eye-tracking data, in: Proceedings of the 9th international conference on Computer supported collaborative learning-Volume 1, International Society of the Learning Sciences, 2009, pp. 78-82.
[18] S. Papert, I. Harel, Constructionism. Norwood, in, NJ: Ablex Publishing, 1991.
[19] ACM/IEEE-CS, Joint Task Force on Computing Curricula. 2013. ACM/IEEE Computing Curricula 2013 Final Report. http://www.acm.org/education/CS2013-final-report.pdf, (2013).
[20] L. Johnson, S. Adams Becker, V. Estrada, A. Freeman, The NMC Horizon Report: 2015 Museum Edition, ERIC, 2015.
[21] L. Buechley, M. Eisenberg, J. Catchen, 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, ACM, 2008, pp. 423-432.
[22] P. Blikstein, Gears of our childhood: constructionist toolkits, robotics, and physical computing, past and future, in: Proceedings of the 12th international conference on interaction design and children, ACM, 2013, pp. 173-182.
[23] O.S. Iversen, R.C. Smith, P. Blikstein, E.-S. Katterfeldt, J.C. Read, Digital fabrication in education: Expanding the research towards design and reflective practices, *International Journal of Child-Computer Interaction*, **5** (2016) 1-2.
[24] J.C. Adams, A.R. Webster, What do students learn about programming from game, music video, and storytelling projects?, in: Proceedings of the 43rd ACM technical symposium on Computer Science Education, ACM, 2012, pp. 643-648.
[25] E.R. Kazakoff, A. Sullivan, M.U. Bers, The effect of a classroom-based intensive robotics and programming workshop on sequencing ability in early childhood, *Early Childhood Education Journal*, **41** (2013) 245-255.
[26] K. Kahn, Toontalk-steps towards ideal computer-based learning environments, *A Learning Zone of One's Own: Sharing Representations and Flow in Collaborative Learning Environments*, (2004) 253-270.
[27] R.M. Ryan, E.L. Deci, Intrinsic and extrinsic motivations: Classic definitions and new directions, *Contemporary educational psychology*, **25** (2000) 54-67.
[28] P.R. Pintrich, A motivational science perspective on the role of student motivation in learning and teaching contexts, *Journal of educational Psychology*, **95** (2003) 667.
[29] F. Guay, C.F. Ratelle, J. Chanal, Optimal learning in optimal contexts: The role of self-determination in education, *Canadian Psychology/Psychologie canadienne*, **49** (2008) 233.
[30] D. Fortus, Attending to affect, *Journal of Research in Science Teaching*, **51** (2014) 821-835.

[31] E.-S. Katterfeldt, N. Dittert, H. Schelhowe, Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops, *International Journal of Child-Computer Interaction*, **5** (2015) 3-10.
[32] M.N. Giannakos, L. Jaccheri, What motivates children to become creators of digital enriched artifacts?, in: Proceedings of the 9th ACM Conference on Creativity & Cognition, ACM, 2013, pp. 104-113.
[33] N. Vos, H. Van Der Meijden, E. Denessen, Effects of constructing versus playing an educational game on student motivation and deep learning strategy use, *Computers & Education*, **56** (2011) 127-137.
[34] R.M. Ryan, E.L. Deci, Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being, *American psychologist*, **55** (2000) 68.
[35] M.A. Just, P.A. Carpenter, Using eye fixations to study reading comprehension, *New methods in reading comprehension research*, (1984) 151-182.
[36] K. Rayner, Eye movements in reading and information processing: 20 years of research, *Psychological bulletin*, **124** (1998) 372.
[37] H. Jarodzka, K. Scheiter, P. Gerjets, T. Van Gog, In the eyes of the beholder: How experts and novices interpret dynamic stimuli, *Learning and Instruction*, **20** (2010) 146-154.
[38] K. Rayner, K.H. Chace, T.J. Slattery, J. Ashby, Eye movements as reflections of comprehension processes in reading, *Scientific studies of reading*, **10** (2006) 241-255.
[39] M.-J. Tsai, H.-T. Hou, M.-L. Lai, W.-Y. Liu, F.-Y. Yang, Visual attention for solving multiple-choice science problem: An eye-tracking analysis, *Computers & Education*, **58** (2012) 375-385.
[40] C. Aschwanden, M. Crosby, Code scanning patterns in program comprehension, in: Proceedings of the 39th Hawaii International Conference on System Sciences, 2006.
[41] R. Bednarik, M. Tukiainen, An eye-tracking methodology for characterizing program comprehension processes, in: Proceedings of the 2006 symposium on Eye tracking research & applications, ACM, 2006, pp. 125-132.
[42] R. Bednarik, Expertise-dependent visual attention strategies develop over time during debugging with multiple code representations, *International Journal of Human-Computer Studies*, **70** (2012) 143-155.
[43] P. Romero, R. Lutz, R. Cox, B. du Boulay, Co-ordination of multiple external representations during Java program debugging, in: Human Centric Computing Languages and Environments, 2002. Proceedings. IEEE 2002 Symposia on, IEEE, 2002, pp. 207-214.
[44] B. Sharif, M. Falcone, J.I. Maletic, An eye-tracking study on the role of scan time in finding source code defects, in: Proceedings of the Symposium on Eye Tracking Research and Applications, ACM, 2012, pp. 381-384.
[45] P. Hejmady, N.H. Narayanan, Visual attention patterns during program debugging with an IDE, in: Proceedings of the Symposium on Eye Tracking Research and Applications, ACM, 2012, pp. 197-200.
[46] S. Pietinen, R. Bednarik, M. Tukiainen, Shared visual attention in collaborative programming: a descriptive analysis, in: proceedings of the 2010 ICSE workshop on cooperative and human aspects of software engineering, ACM, 2010, pp. 21-24.
[47] M.K. Eckstein, B. Guerra-Carrillo, A.T.M. Singley, S.A. Bunge, Beyond eye gaze: What else can eyetracking reveal about cognition and cognitive development?, *Developmental cognitive neuroscience*, (2016).

[48] S. Papavlasopoulou, K. Sharma, M. Giannakos, L. Jaccheri, Using Eye-Tracking to Unveil Differences Between Kids and Teens in Coding Activities, in: Proceedings of the 2017 Conference on Interaction Design and Children, ACM, 2017, pp. 171-181.
[49] F. Paas, A. Renkl, J. Sweller, Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture, *Instructional science*, **32** (2004) 1-8.
[50] J. Sweller, J.J. Van Merrienboer, F.G. Paas, Cognitive architecture and instructional design, *Educational psychology review*, **10** (1998) 251-296.
[51] M.A. Just, P.A. Carpenter, A theory of reading: From eye fixations to comprehension, *Psychological review*, **87** (1980) 329.
[52] M.A. Just, P.A. Carpenter, Eye fixations and cognitive processes, *Cognitive psychology*, **8** (1976) 441-480.
[53] M.A. Just, P.A. Carpenter, The role of eye-fixation research in cognitive psychology, *Behavior Research Methods*, **8** (1976) 139-143.
[54] M. Hegarty, M.-A. Just, Constructing mental models of machines from text and diagrams, *Journal of memory and language*, **32** (1993) 717-742.
[55] R.E. Mayer, Unique contributions of eye-tracking research to the study of learning with graphics, *Learning and instruction*, **20** (2010) 167-171.
[56] P.A. Kirschner, J. Sweller, R.E. Clark, Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching, *Educational psychologist*, **41** (2006) 75-86.
[57] R. Moreno, When worked examples don't work: Is cognitive load theory at an impasse?, *Learning and Instruction*, **16** (2006) 170-181.
[58] F. Paas, J.E. Tuovinen, J.J. Van Merrienboer, A.A. Darabi, A motivational perspective on the relation between mental effort and performance: Optimizing learner involvement in instruction, *Educational Technology Research and Development*, **53** (2005) 25-34.
[59] M. Resnick, J. Maloney, A. Monroy-Hernández, N. Rusk, E. Eastmond, K. Brennan, A. Millner, E. Rosenbaum, J. Silver, B. Silverman, Scratch: programming for all, *Communications of the ACM*, **52** (2009) 60-67.
[60] S. Bakker, E. van den Hoven, A.N. Antle, MoSo tangibles: evaluating embodied learning, in: Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction, ACM, 2011, pp. 85-92.
[61] R. Jacob, K.S. Karn, Eye tracking in human-computer interaction and usability research: Ready to deliver the promises, *Mind*, **2** (2003) 4.
[62] J.H. Goldberg, M.J. Stimson, M. Lewenstein, N. Scott, A.M. Wichansky, Eye tracking in web search tasks: design implications, in: Proceedings of the 2002 symposium on Eye tracking research & applications, ACM, 2002, pp. 51-58.
[63] L. Cowen, L.J. Ball, J. Delin, An eye movement analysis of web page usability, in: People and Computers XVI-Memorable Yet Invisible, Springer, 2002, pp. 317-335.
[64] L. Hall, C. Hume, S. Tazzyman, Five Degrees of Happiness: Effective Smiley Face Likert Scales for Evaluating with Children, in: Proceedings of the The 15th International Conference on Interaction Design and Children, ACM, 2016, pp. 311-321.
[65] B. Kuvaas, Work performance, affective commitment, and work motivation: The roles of pay administration and pay level, *Journal of Organizational Behavior*, **27** (2006) 365-385.
[66] V. Venkatesh, C. Speier, M.G. Morris, User acceptance enablers in individual decision making about technology: Toward an integrated model, *Decision sciences*, **33** (2002) 297-316.

[67] W.J. Conover, W.J. Conover, Practical nonparametric statistics, (1980).
[68] S.S. Shapiro, M.B. Wilk, An analysis of variance test for normality (complete samples), *Biometrika*, **52** (1965) 591-611.
[69] J. Denner, L. Werner, S. Bean, S. Campe, The girls creating games program: Strategies for engaging middle-school girls in information technology, *Frontiers: A Journal of Women Studies*, **26** (2005) 90-98.
[70] Y.B. Kafai, Q. Burke, Constructionist gaming: Understanding the benefits of making games for learning, *Educational psychologist*, **50** (2015) 313-334.
[71] G. Fessakis, E. Gouli, E. Mavroudi, Problem solving by 5–6 years old kindergarten children in a computer programming environment: A case study, *Computers & Education*, **63** (2013) 87-97.
[72] J. Denner, L. Werner, E. Ortiz, Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts?, *Computers & Education*, **58** (2012) 240-249.
[73] D.N. Perkins, C. Hancock, R. Hobbs, F. Martin, R. Simmons, Conditions of learning in novice programmers, *Journal of Educational Computing Research*, **2** (1986) 37-55.
[74] R.L. Oliver, Effect of expectation and disconfirmation on postexposure product evaluations: An alternative interpretation, *Journal of applied psychology*, **62** (1977) 480.
[75] S.-H. Liu, H.-L. Liao, J.A. Pratt, Impact of media richness and flow on e-learning technology acceptance, *Computers & Education*, **52** (2009) 599-607.
[76] C.S. Lin, S. Wu, R.J. Tsai, Integrating perceived playfulness into expectation-confirmation model for web portal context, *Information & management*, **42** (2005) 683-693.
[77] H.-P. Shih, Using a cognition-motivation-control view to assess the adoption intention for Web-based learning, *Computers & Education*, **50** (2008) 327-337.
[78] L. Abeysekera, P. Dawson, Motivation and cognitive load in the flipped classroom: definition, rationale and a call for research, *Higher Education Research & Development*, **34** (2015) 1-14.
[79] J. Hyönä, The use of eye movements in the study of multimedia learning, *Learning and Instruction*, **20** (2010) 172-176.
[80] S. Nevalainen, J. Sajaniemi, Comparison of three eye tracking devices in psychology of programming research, *6th Annual Psychology of Programming Interest Group*, (2004) 170-184.
[81] P. Qvarfordt, S. Zhai, Conversing with the user based on eye-gaze patterns, in: Proceedings of the SIGCHI conference on Human factors in computing systems, ACM, 2005, pp. 221-230.

Appendix

Table A1: Normality test (Shapiro–Wilk test, p-values, for the three levels of perceived learning, intention and excitement).

Variable	Learn (3, 4, 5)	Intention (3, 4, 5)	Excitement (3, 4, 5)
Fixation duration	0.13, 0.74, 0.81	0.45, 0.41, 0.44	0.27, 0.74, 0.08
Saccade amplitude	0.44, 0.42, 0.83	0.56, 0.43, 0.85	0.73, 0.13, 0.58
Saccade direction	0.31, 0.75, 0.54	0.48, 0.31, 0.69	0.45, 0.12, 0.45