Case Study

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Individual Creativity and Career Choices of Pre-teens in the Context of a Math-Art Learning Event

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Abstract: A sample of 392 students (aged 12-13 years, M± SD: 12. 52% girls) completed a learning module integrating informal hands-on mathematics and arts activity (extending STEM to STEAM). Within a 140 minute workshop period participants worked with commercially available '4Dframe' Math and STEAM learning toolkits to design and create original, personal and individual geometrical structures. Two science pedagogues acted as tutors supervising the process and intervened only when needed. A pre-/post-test design monitored individual creativity, relative autonomy, and career choice preference. Path analysis elaborated the role of creativity (measured with two subscales: act and flow), and it showed that post-act, post-flow as well as relative autonomy are valuable predictors of career choices. Similarly, pre-creativity scores were shown to significantly predict the related post-scores: act and flow. As a consequence, our STEAM module was shown to trigger both the creativity level and the career choice preferences. Conclusions for appropriate educational settings to foster STEAM environments are discussed.

Keywords: STEAM; math learning; inquiry-based; hands-on; art; informal learning; motivation; career choice.

1 Introduction

There are numerous reports and policy documents (EU, 2015; KOFAC, 2017; BERA 2017) referred to in the education research literature today that point out various social and societal ills are related to workforce changes. There is a rising need for employees in STEM fields, coming at a time when success in STEM education seems elusive, due to the ever-present computing technology. The gap between the urgencies of today and tomorrow will not be solved by everyone becoming a programmer or some other STEM specialist, but rather a learner and a creator of new ways to understand. Tomorrow will place a higher value upon creative thinking and teaching others, including machines. *The Horizon Report Europe 2014 (Schools Edition)* already calls attention to all of the main components of the changes taking place, and it attempts to identify the most likely influential tendencies, challenges, and technologies in teaching, learning, and creative research with respect to the period extending to 2020 (EU, 2015). By projecting this prognosis onto the present and future of mathematics learning and first and foremost the complex integrative possibilities of problem-solving, it is worth highlighting several less discussed potentials inherent in the interconnections between the school disciplines and the pedagogical approaches (Salmi, Thuneberg & Bogner, F. 2020), especially in the case of STEAM (Science, Technology, Engineering, Arts, Mathematics) integration.

A crucial element in multidisciplinary learning processes is the project method (Dewey, 1980; Burnard et al., 2015; Lähdesmäki & Fenyvesi, 2017) throughout which students can actively participate in planning and selecting the lessons' learning content, the learning methods, and the practices to be applied. Maintaining the students' sense of motivation (Deci & Ryan, 2002) and engagement remains the key to establishing their understanding of the goals and having a clear perception of the significance of learning about the given topic (Zoldasova & Prokop, 2006). Small groups are helpful when teachers need to reduce their actions to those of tutors (Johnson & Johnson, 2017). Another crucial aspect is for the knowledge gained in school to be linked to that acquired outside of school and vice versa (Burns & Silbey, 2008; Pitkänen-Huhta & Rothoni, 2018). The learning process must therefore make room for intellectual curiosity (Görlitz, 1987), creative

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expression (Barbot, Besançon & Lubart, 2011), the gaining of experience (Dewey, 1980) and the exploration of the various ways in which knowledge can be applied (Mack, 2006). Among the values stressed throughout this process, sustainability and its practices as a basis for individual and collaborative activity are also found (FNCC, 2014).

Art and creativity form an integrative component in the STEAM approach (Yakman & Lee, 2012). Due to the differences between the traditions (Görlitz, 1987), contexts and possible goals of diverse mathematics and art education approaches, their notions of the learning process, learning activities and collaborative learning and their approaches to teaching, problem-solving, creativity, and understanding of originality and authorship are radically different (Sochacka, Gyuotte & Walther, 2016). However, through meticulous comparison several joint potentials may emerge, which can be re-contextualized and further developed into a joint mathematics and arts education framework based on the aesthetics of interdisciplinarity that may: (a) provide motivation and engagement for students and their teachers; (b) enrich mathematics and arts learning in a meaningful way; and (c) enhance inter- and transdisciplinary STEAM learning frameworks with strong cultural embeddedness and social impact, where art is an integrative and transformative element of the STEAM approach and not just a vehicle for STEM learning (Lähdesmäki & Fenyvesi, 2017).

Both policy documents and research tells us that students must learn how to learn new ways to approach novel problems, gain new ideas and skills and create and use tools in innovative ways (Schmid & Bogner, 2015). Education that focuses on methods that keep students isolated from real world problems and from pursuing their own goals can no longer be the norm (Salmi, Vainikainen & Thuneberg, 2015). Flexibility and the awareness that variation is the root of intelligence ought to be the goal of education so that it prepares young people to creatively apply information, knowledge and tools in new and previously unexpected ways (Szabó, Fenyvesi, Soundararaj & Kangasvieri, 2019). All this is to be done in both the offline and online community with others and crossing former disciplinary boundaries (Sotiriou, Bybee & Bogner, 2017). Breaking down 'subject silos' by developing the multidisciplinary and phenomenon-based forms of learning, such as the extension of STEM into STEAM wherein the arts are integrated into problem-solving, adds a creative and human dimension that can bring learning to life (Burnard et al., 2015). Activities that involve a genuine, human context while additionally turning the world outside of schools into a learning opportunity are an essential component in STEAM's integrative approach, which is quickly spreading around the globe and especially in Europe's leading educational communities (EU, 2015). This is very much related to the approach to twenty-first-century skills where the starting points are the five habits of mind: imagination, inquisitiveness, persistence, collaboration, and discipline. These further consist of soft skills such as developing techniques, playing with possibilities, crafting and improving, reflecting critically, daring to be different, wondering and questioning and, tolerating uncertainty (Lucas, Claxton & Spencer, 2013). According to policy documents, these are also the hallmarks of the educational system of the near future (Burnard & Colucci-Gray, 2020).

In this study, autonomy was considered as an important prerequisite for learning. According to Self-Determination Theory (SDT), autonomy is one of the three basic psychological needs which have to be fulfilled in order to be able to function and learn optimally. In this study, we tested this theory in the informal STEAM-learning environment. The degree of self-determination can be identified by analyzing the motivational and self-regulatory styles of pupils and calculating the Relative Autonomy Index (RAI), which is explained in detail in the Methods section. Experienced autonomy means choice and a possibility to control one's own actions (Ryan & Connell, 1989), to realize intentions, and to avoid undesired events (Skinner & Edge, 2002). In autonomous behaviour, agency experience and being a source of origin is essential (Thuneberg et al., 2018).

As has been reported in several studies, the autonomy of the learner is essential for meaningful learning (Reeve, 2002; Kaplan, 2008; Zimmerman & Schunk, 2007). Recent results from the research literature (Salmi & Thuneberg, 2017) and meta-analyses (Thuneberg et al., 2018) underline the role of autonomy, and this is especially the case in informal learning settings (Thuneberg, Salmi & Fenyvesi, 2017) where the cause of behaviour is interest in the activity itself, curiosity or pure enjoyment. These are typical features and characteristics of out-of-school education and informal learning settings such as hands-on workshops or science centres (Gardner, 1991; Rennie, 2014).

Gender autonomy seems to be important in the process of future studies orientation and career choices (Woolnough, 1994). Informal learning sources seem to have a strong impact, especially on those youngsters who are making 'unconventional' but successful choices for their future (Salmi, 2003) especially while breaking "traditional" stereotypical gender-related career choices such as ICT or technology (Buser et al., 2012; Hidalgo, 2017).

The objectives of our study were four-fold: first, to identify the effect of visual reasoning and experienced autonomy on future study plans and science-orientated career choices; second, to characterize the role of the STEAM-module as intervention; third, to identify the influence of creativity in this process; and fourth, to take gender into account as a background variable.

2 Methods & Procedures

Participants came from the Helsinki capital area (N=392). Of these, 52% were girls (n=204) and 48% boys (n=188), and the average age was 12 years and 4 months (Std. Dev. = .32). Altogether, 11 schools contributed to our convenience sample from all the schools invited to attend the workshop. Schools could participate without charge and use public transportation as part of the routine out-of-school education tradition included in the Finnish National Core Curriculum for Basic Education. The study complied with empirical permission requirements and ethical principles.

Visual Reasoning was monitored using the Raven test. This test has been successfully utilized earlier in several formal and informal learning contexts as well as in meta-studies (Thuneberg & Salmi, 2018). Many researchers suggest that thinking skills are essential to effective learning. *Making a Science of Education* (Alberts, 2009) the editorial in the thematic issue of the journal *Science* (Science, 2009) is still more than timely, as it demanded that a great deal of high-quality research should be performed by focussing on the utilisation and effects of new technologies in both school and informal learning environments. For example, Greenfield (2009) considers the Raven test a useful method regarding thinking skills. The cognitive measure was a visual reasoning and learning capacity test: Raven Standard Progressive Matrices (Raven, Raven, & Court 2003). The main elements in the common cognitive ability are the capacity to learn and the capacity to embrace and remember the knowledge once learned. The Raven test measures non-verbal cognitive skills; the particular ways in which people apply their minds to solving problems. It provides a reliable standardised tool for comparing individuals' learning abilities compared to the representative age group, irrespective of sex. In each test item, the subject is asked to identify the missing element that completes a pattern. The test contains 60 items that have been divided into five sets (A, B, C, D, E). Each of these groups contains 12 different tasks.

The Deci-Ryan scale measuring autonomous motivation was based on Self-determination theory (SDT) (Ryan & Deci, 2000; Deci & Ryan, 2002). It was administered as a pre-test, and its effect analysed in the Structural equation model in order to reveal the purified influence of short-time situation motivation in the workshop context. The Deci-Ryan Motivation (SRQ-A: Self-Regulation Quality – Academic) scale had 32 standardized items with four Likert options: 1 = not at all true, 2 = not nearly true, 3 = somewhat true, 4 = totally true. The questions corresponded with the self-regulation styles on the self-determination continuum. For example, the students were asked the reasons why they did their homework or tried to answer difficult questions during lessons. The summative variables forming the self-determination continuum from external to intrinsic were as follows: External, Introjected, Identified, and Intrinsic. Based on the formula used by Ryan and Connell and presented in the validation article of the SRQ-A (Ryan & Connell, 1989), the Relative Autonomy Index (RAI) was calculated for the summative variables (i.e. External, Introjected, Identified, Intrinsic). The RAI described the overall relative autonomy level of the pupil. The positive plus-sign in RAI indicated that the experience was rather autonomous, and the negative minus-sign that one relied more on others than trusting in one-self. The reliability of the SRQ-A was good, Cronbach's α=.917, 32 items.

In addition to overall motivation a specific science motivation questionnaire (SMQ) was also administered in a pre- and post-test (Bakerman, 2005). The measurement tool covered two subscales: IM 'intrinsic motivation' and SD 'self-determination' (modified by Schumm & Bogner, 2016). Both subscales consisted of 4 items per subscale, and each followed a 5-point Likert scale pattern ranging from 'never' (1) to 'always' (5). Items included, for example: 'Understanding science will benefit me in my career', 'I am confident I will do well on science tests', and 'Knowing science will give me a career advantage'.

The Creativity measure (CREAT) consisted of 10 items originating from Miller and Dumford (2016) and modified by Conradty and Bogner (2017). Items included, for example: 'Tried to generate as many ideas as possible when approaching a task', 'Looked at a problem or task from a different angle to find a solution', and 'Been fully immersed in your work on a problem or task'.

The pupil's visual reasoning competencies were measured using Raven Standard Progressive Matrices (Raven, Raven & Court, 2003). The test consists of five sets of twelve items, where the pupils have to find the right solutions during six opportunities to identify the missing element.

2.1 Educational intervention

The "Math & Art" workshop was based on a process of constructing a work, which involved art, creative geometrical construction, engineering, and technology, for example, by building large, artificial, moving creatures as a fusion of art and technology (similarly to Theo Jansen's "strandbeests", which are at the same time powerful examples of the interaction between the artistic imagination and the applied geometrical and engineering genius) – with curiosity, imagination, and play (Salmi, Thuneberg & Fenyvesi 2017). The commercially available 4Dframe hands-on educational toolkit is based on the structural analysis and geometric formalization of building techniques in utilizing the construction guidelines of traditional, light-structured buildings (Fenyvesi, Koskimaa & Lavicza, 2015) as well as other aesthetic and artistic sources (Sochacka, Gyuotte & Walther, 2016). The use of the toolkit in similar contexts has been introduced in several studies earlier (e.g. Fenyvesi et. al, 2016; Fenyvesi et. al, 2018; Fenyvesi et. al, 2019).

Small groups of 3 pupils could make use of one construction toolkit, which consisted of hundreds of 2-30 cm long plastic tubes and various types of connectors, flexible enough to construct "unbreakable" modules or spatial formations. The plastic "tubes" and connecting "stars" were like "zeros" and "ones". The pupils knew this is the basis for programming computers. Now as an analogy, they were creating concrete, completely different things with very basic materials by combining tubes and star connectors in their own way with different solutions from exactly the same materials. The Math & Art workshop took place in an open learning environment on the university premises. It offered an opportunity to use, test, explore and learn in small groups of two to four pupils. Groups were formed on a free-choice and voluntary basis with the assistance of each class teacher who had experience forming groups for collaborative learning. They could test, create and build freely within a 140 minute time period with small breaks. The project started with a ten-minute introduction of the 4Dframe toolkit to present its basic characteristics and to call attention to its creative potentials in geometrical and mechanical modeling, both in playful learning and scientific research, and to familiarize the pupils with some examples of how the toolkit can make the "imaginable", such as the 3-dimensional projections of higher-dimensional structures observable and tangible in our 3-dimensional reality. Two science education pedagogues supervised as tutors, mostly by observing, encouraging, and providing requested information on demand, as well as suggesting problems to explore and challenges to resolve during the process. The class teacher only took care of practicalities.

Pupils were encouraged to design and create their own, imaginary structures with 4Dframe. The task was to create "an imaginary equipment which is not bigger than 20 cm x 30 cm x 40 cm, and which preferably has moving parts and gets its energy from the wind". An overall plan was required to provide simple drawings and short explanations. They were also encouraged to modify plans according to the empirical evidence they confronted during the process. There were student teams which started to work on scientific models, which they had creatively modified in a playful process (Figure 1), imaginary creatures, machines, and other mechanical structures based on wind energy (Figure 2, 3). The participating children could use their individual and collective imagination, move around freely in the space, produce, fabricate, or create amusement. In the open learning environment, there was a "wind tunnel", a real, small-scale piece of scientific test equipment to test the efficacy of the utilization of wind power and in this way combine the imaginative and creative aspects of the workshop activity with scientific and objective testing. The pupils had an opportunity to test, try and improve their "4Dframe creation" and its structure any time during the process, also by using the wind tunnel. With the help of the wind tunnel, the students could easily test and improve their equipment to make it more efficient in transforming wind energy into movement. In the end, all products were presented to their peers and documented using photos or videos.

All the variabilities offered opportunities for conceptualizing, modeling, or analyzing structures relevant, for instance, to geometry and art (Fenyvesi, Koskimaa & Lavicza 2014). The step-by-step approach demanded empirical testing, evidence, and analysis of each stage in the construction, and thus offered a good platform for creative STEAM education.

3 Results

The principal component analysis on the creativity variables (CREAT) resulted in two components (cut point eigenvalues > 1). Those two components together explained 50% of the pre-test variance and 58% of the post-test variance. The first component was labeled "Act" and consisted of five items: 1. *Combined dissimilar concepts to create a novel idea* (loading pre: .726; loading post: .703), 2. *Incorporated a previously used solution in*

Figure 1: The 4Dframe Buckyball and carbon nanotube was built in a collaborative problem-solving process. In the playful flow of the team's activity, the carbon nanotube was creatively transformed into a funny costume.

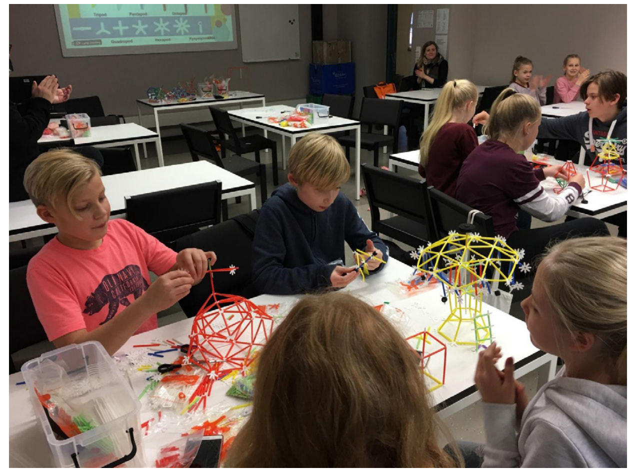

Figure 2: Imaginative, creative windmills, models of geometric amusement park game designs.

Figure 3: Imaginative, creative windmills, models of geometric amusement park game designs.

a new way (pre: .715; post: .781), 3. *Made a connection between a current problem or task and a related situation* (pre: .667; post: .735), 4. *Imagined a potential solution in a new way* (pre: .642; post: .688) and 5. *Tried to generate as many ideas as possible when approaching a task* (pre: .466; post: .614). The second component "Flow" consisted of: 1. *Lost track of time when intensely working* (pre: .721; post: .854), 2. *Felt that work was automatic and effortless during an enjoyable task* (pre: .712; post: .680) and 3. *Being fully immersed in your work on a problem or a task* (pre: .710; post: .761). (Two items were omitted because of similar and high cross-loadings).

The principal component analysis on the "Career" variable resulted in two components: Career and Intrinsic motivation. They explained 66% in the pre-test and 72% in the post-test. The first component, Career, which was used in this study, consisted of: 1. *Understanding science will benefit me in my career* (pre: .723; post: . 823), 2. *I am confident I will do well on science tests* (pre: .850; post: .882), 3. *Learning science will help me get a good job* (pre: .784; post: .802) and 4. *I will use science problem-solving skills in my career* (pre: .707; post: .763).

In Table 1, the statistical descriptors are presented in total and for girls and boys. Based on a one-way analysis of variance, none of the differences between boys and girls were statistically significant. The change between the pre- and post-test was non-significant based on the paired-samples' t-tests between Act pre and Act post and between Flow pre and Flow post. However, the change was significant between Career pre and Career post ($t=1.993$, $p=.047$), and the further analysis in split groups showed that the post-test was significantly lower than the

Table 1: Statistical descriptives (M=Mean, SD= Standard Deviation).

	N girls	M	SD	N boys	M	SD	Total M	SD	Min	Max
Raven	199	34.357	6.680	181	33.193	7.517	33.803	7.106	2	48
RAI	197	.211	2.066	170	.160	1.849	.187	1.966	-7.229	7.210
CREA act pre	203	2.397	.551	180	2.399	.548	2.398	.549	1.00	4.00
CREA act post	179	2.423	.653	157	2.447	.531	2.434	.599	1.00	4.00
CREA flow pre	203	2.468	.652	180	2.547	.628	2.505	.641	1.00	4.00
CREA flow post	179	2.430	.653	157	2.543	.6.88	2.483	.671	1.00	4.00
Career pre	203	3.562	.761	182	3.588	.780	3.575	.769	1.50	5.00
Career post	180	3.431	.837	158	3.575	.873	3.498	.856	1.00	5.00

Table 2: Bivariate correlations of the variables.

	career pre	career post	Raven	RAI	CREA act pre	CREA flow pre	CREA ACT post
career post	.610***						
Raven	-.081	-.008					
RAI	.190***	.232**	.042				
CREA act pre	.338***	.306***	-.073	.156**			
CREA flow pre	.301***	.259***	-.042	.276***	.475***		
CREA_act post	.325***	.496***	-.014	.227***	.528***	.378***	
CREA flow post	.312***	.418***	.013	.297***	.321***	.576***	.528***

pre-test for the girls (t=2.647, p=.009), but non-significant for the boys.

4 SEM Path analysis

The bivariate correlations (Table 2) between the variables were analyzed in order to exclude the non-significant variables from the path-analysis. The autonomous motivation (RAI), gender, Act pre, Flow pre, and Career pre were used as covariates to analyse their effects after the Math & Art workshop on the variables measured (Act post, Flow post, and Career post). The Raven test was not included in the model because the correlation analysis showed that all its correlations with the other variables were non-significant. Gender was non-significant and did not contribute to the model. The final model containing only significant effects was found to fit the data well: χ^2= 11.137, df=7, p=.133; NFI=.985. TLI=.977. CFI=.994; RMSEA=.039.

The final path model is presented in Figure 4. The standardized beta-coefficients are shown with the indicators of significance (*=p<.05. **=p<.01. *** p<.001) and the total explanation by R2.

The analysis of the covariances showed that the creativity component Flow-pre (measured before the educational intervention) correlated moderately with all other variables in the pre-test situation. Career-pre had, in addition, a moderate correlation with the creativity component Act-pre and a smaller one with Relative autonomy, RAI. When those effects were controlled, Act-pre and Flow-post (measured after the intervention) were found to moderately (42%) predict Act-post. Flow-pre strongly predicted Flow-post. Relative autonomy RAI and the career component Career-pre (both measured before the intervention) had a smaller effect on Flow-post; together they explained 37% on its variance. Career-pre, Act-post, and to a smaller degree, Flow post predicted Career-post.

It is important to note that, in addition to the direct effects explained here, there were also indirect effects (for example, Flow-pre had a direct effect on Flow-post, but also an indirect effect via Flow-post on Act-post and Career-post).

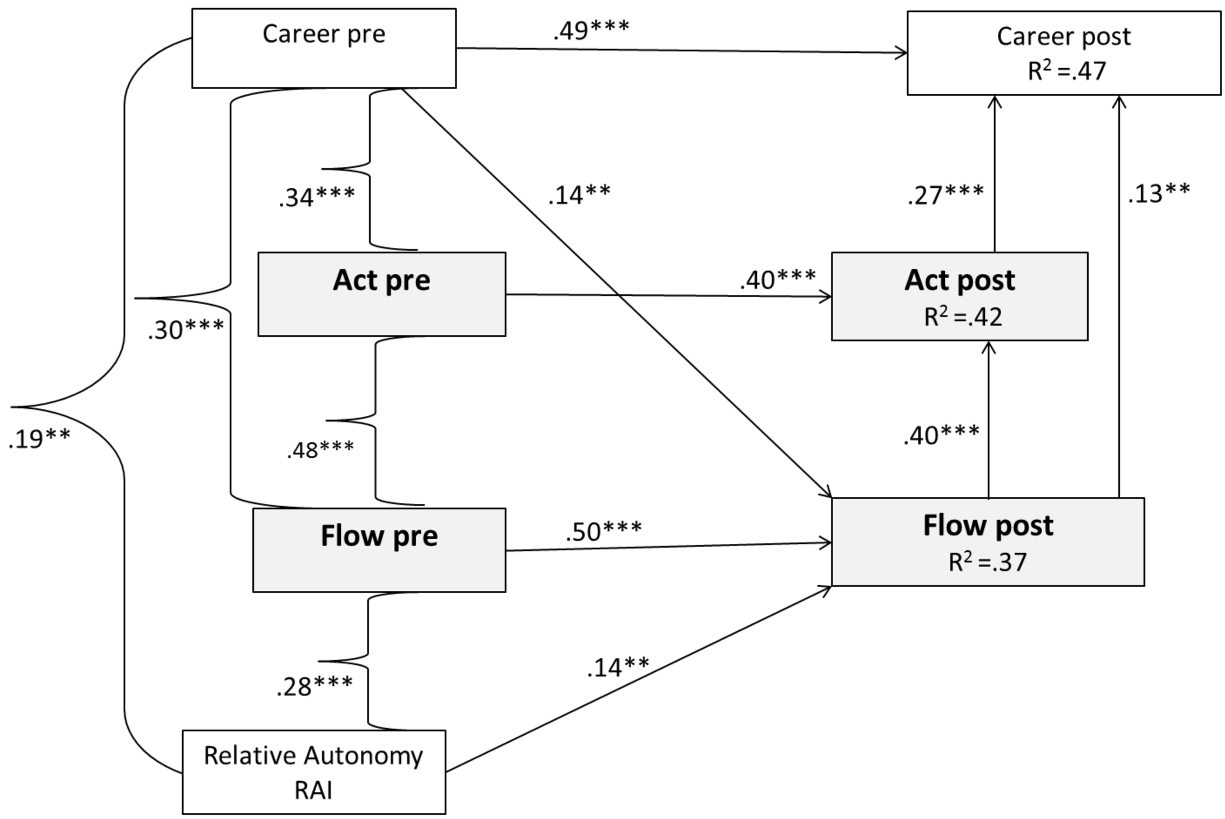

Figure 4: The final path model.

By applying SEM-modeling, it is likely we could somewhat better capture the real world situation than would have been possible by using only simple bi-variate correlation analysis. The total explanation of the variables on Career-post was 47%. By Cohen's standards (1988), the total explanation is not large. However, it has been noted that these standards do not depict findings well in social and psychological sciences (Weinfurt, 1995; Thompson, 2006; Bosco, Aguinis, Singh, Field & Pierce, 2015), and as Bosco, Aguinis, Singh, Field and Pierce (2015) state, these criteria lead to an underestimation of the effects: "Specifically, results indicate that the distribution of the effect sizes exhibits tertile partitions at values approximately one-half to one-third those intuited by Cohen (1988). In addition, results indicate substantial variability in the effect sizes across research domains and types of relationships".

5 Discussion

Career choice preferences along with the relative autonomy experience were shown to interact considerably. A path analysis elaborated the role of individual creativity (measured with two subscales: act and flow) with regard to the other variables, whereas post-act and post-flow, as well as relative autonomy, were shown to intervene with career choice preferences. Pre-creativity scores significantly influenced the related post-scores, Act and Flow. Pre-creativity scores were significantly related to the related post-scores, Act and Flow. Thus, our STEAM module affected the career choice preferences, and the creativity level had a supportive role here. Although the visual reasoning measured by the Raven test has in various studies turned out to be an essential factor when explaining informal learning, in this study this was not the case; no significant connections were found. Gender had no role in the career choices or creativity variables based on the path-analysis. However, based on a simple t-test analysis, the scores of the science motivation (SMQ) decreased among the girls after the short workshop. This result might be in concordance with earlier literature findings (Hong et al., 2013; Farence & Joyce, 1999), or perhaps our STEAM approach did not inspire some of the girls, but we could not trace the reason for this phenomenon.

Support for autonomy has shown to enhance science learning attitudes. Earlier studies (e.g. Jalil et al., 2009) have provided evidence that those pedagogical solutions which encourage and emphasize autonomy by allowing pupils to first experiment on their own with different types of hands-on experiments lead to intrinsic motivation and positive attitudes towards science. This also seems to be the case in similar learning processes related to creativity (Thuneberg, Salmi & Fenyvesi, 2017). This, thus, reflects some of the essential twenty-first-century soft skills, for example, daring to be different and simultaneously tolerating uncertainty (Lucas, Claxton & Spencer, 2013). Also, the role of extra-curricular activities and tutorial support play key roles in this process (Jidesjö, 2008). This seems to be the implication of the result of the Math & Art workshop, as well.

Opportunities for utilizing creative thinking encouraged the pupils to apply previously learned solutions in a new way. They also started to use their imagination independently to find a different potential solution to the practical problem. This was shown in their growing ability for reframing, for example, seeing things in a new light or observing the phenomenon from a different angle or perspective (Lucas, Claxton & Spencer, 2013; Mattila, 2000; Olier, 2017). The STEAM method also developed the pupils' skills for team-work, as they were becoming more cooperative to join together to collect dissimilar concepts to create novel ideas.

Hands-on workshops gave a lot of freedom for the pupils to test, play and create new models (Scharfenberg & Bogner, 2010). The atmosphere was conducive for learning and very joyful, but never become too restless or chaotic, which sometimes happens when interacting with some so-called soft variables (e.g. Franke & Bogner 2013). Additionally, the absence of classroom frames allows an atmosphere of less external control and turns the teacher's role more towards a tutorial or mentor role (Goldschmidt et al., 2016). Especially the latter often fails, as classroom teachers are not used to giving up their leader role and taking a backstage role. However, if the environment is secure and the inordinate uncertainties of informal environments are controlled, educational outcomes are promising. This observation was also supported by our path-model results. They indicated development through an intensive, 'flow' type of feeling, such as losing track of time while studying intensively and feeling that the project and assigned task is effortless, automatic, and enjoyable. The more autonomous pupils feel, the more likely they are to have intrinsic motivation while learning science. Hands-on lessons need guidance and actions to prevent overload, especially in informal settings or when new tools are coming into play. Our results also support the meta-data research results on informal learning settings (Thuneberg & Salmi, 2018). Autonomy had an effect on how the pupils experienced mathematical-artistic learning.

The main results of this study confirmed several earlier findings in informal learning settings in regard to how momentary situation motivation transforms into intrinsic motivation with a deep-learning strategy (Rennie, 2014; Vainikainen et al., 2015). There are also good reasons for generalizing these encouraging results, because these were typical 12-year-old pupils who were attending this Workshop and selected as a sample. This type of out-of-school activities – bridging the gap between formal education and informal learning - are part of the National Curriculum in Finland, (FNCC, 2014) as well. The STEAM-education context seems to be even something more and different than only the sum of its components. This seems to have positive input in regard to their future study plans and career orientations. In consequence, STEAM alone is not the solution to overcome the limitations of science education, but amongst many others it can contribute to and fine-tune effort to overcome or minimize the gap between the reality of STEM education now and the future skills needed by citizens and society.

Data Availability Statement: The data that support the findings of this study are available from University of Helsinki but restrictions availability of these data, which were used under license for the current study, and so are not publicly available however available from the authors upon reasonable request and with permission of University of Helsinki.

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Author Contribution: Hannu Salmi was the leading author of this article. He led the design of study, the data collection and analysis. Helena Thuneberg carried out the statistical analysis of the data. Franz X. Bogner worked on the theoretical context and Kristof Fenyvesi worked on the STEAM-related aspects of the study and contributed to the conclusion.

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Informed Consent: Informed consent has been obtained from all individuals included in this study.

Authorization For The Use Of Human Subjects: Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and in accordance the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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