Article

Exploring Students' Science-Related Career Awareness Changes through Concept Maps

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Abstract: The current article addressed middle school (13–15 years old) students' science-related career awareness (SCA) and aimed to determine the effects of a longitudinal intervention, which focused on integrating career education into science teaching, using a pre- and post-test design. During the intervention, five teaching/learning modules (TLMs) were implemented in science lessons that enabled students to experience being (1) an electrical engineer, (2) a food technologist, (3) a forensic scientist or a civil engineer, (4) a team member of oil catastrophe simulation clean-up team, and (5) a customs' officer. Concept mapping was used to determine the changes in students' SCA. The suitability of this technique was validated through semi-structured focus group interviews. It was found that concept mapping enabled detection of progression in the intervention students' SCA among both boys and girls. The interviews provided valuable input on how students interpreted science-related occupations and relevant competences, when constructing their concept maps. An implication from this study was that SCA supportive teaching and learning modules or other similar teaching methods needed to be an inherent part of science teaching to support students making well informed decisions, either towards or away from science-related careers.

Keywords: science-related career awareness; concept mapping technique; longitudinal intervention; pre-test; post-test design; middle school

1. Introduction

The lack of science, technology, engineering, and mathematics (STEM) professionals is considered a problem in many countries, having negative implications on economic development. For example, European countries such as Estonia, Latvia, Croatia, and Germany are struggling to encourage youth, especially girls, to pursue science-related career paths [1]. This has led to the current situation, where 45.4 % of human resources in science and technology are at a senior age (45–65 years old) among European Union countries [2]. Furthermore, gender differences within science-related fields, like information and communication technology (ICT), engineering, and medicine have been recognized in a range of countries [3,4].

The problem of students not pursuing science-related careers has been linked with various factors, seen as shaping students' attitudes toward science studies and science-related careers. More specifically, several research studies claimed that school science lacks relevance for students' lives, while science content is presented in a boring and theoretical manner, is decontextualized and focuses on conceptual learning, lacks practical work and/or experimental work, and poorly introduces science-related careers to students [5–12].

Supporting students in developing science-related career awareness has been recognized as an important focus for science education [11,13]. In this regard, Tytler and Osborne [11] argue:

> " . . . *Students cannot aspire to that, which they have never seen*". (p. 618)

Nonetheless, science teachers' awareness of the increasing new or 'modern' careers in science and related fields is often lacking [14,15], which hinders their abilities to support students in developing career awareness. Thus, providing teaching and learning modules for science teachers, which introduce science-related careers by incorporating work tasks into science subject teaching, is expected to lead to students' wider acknowledgement about the possible outcomes of learning science.

The current study aims to determine the effects of a three-year long intervention on middle school students' (aged 13–15 years) science-related career awareness (SCA) development. By focusing on adolescence—the stage in cognitive development when students are still forming their interests and deliberating on their career prospects [16]—it is expected that the intervention supports such students in the making of well-informed career decisions, either towards or away from science and science-related fields.

Although there are studies that determined students' career awareness changes, induced by an intervention (e.g., [17,18]), few have addressed middle school students in a longitudinal intervention setting (e.g., [19]). Also, the effects of these studies have been determined, either through self-reported growth in career awareness and perceived applicability of science competences [18,20], or with questionnaires, addressing gains in awareness of various science-related occupations [17].

The current study contributes to the existing literature about longitudinal career awareness supportive intervention effects on middle school students' career awareness and differs from other studies by implementing concept mapping for detecting changes in students' SCA. Concept mapping enables the visualization of someone's mental representations regarding a topic, by showcasing both the concepts and their relationships in a compact format [21]. This characteristic enables an evaluation of the level of constriction or sophistication of someone's science-related career awareness. The following research questions are put forward:

1.　What impact does a three-year intervention, aiming to raise students' SCA, have on students' awareness of (a) science-related occupations and (b) competence requirements for science-related occupations?
2.　What is the impact of the intervention on gender differences in students' science-related career awareness?
3.　How well do concept maps enable to represent students SCA?

1.1. Science-Related Careers and Required Competences

'Science-related careers' and 'STEM (acronym referring to science, technology, engineering and mathematics) careers' are taken as synonyms and broadly relate to a variety of occupations a person may have in science and related fields, such as technology, engineering, and mathematics, during his/her lifetime. Science-related careers are considered in a broad sense to emphasize the applicability of studying science and gaining awareness of relating fields in a variety of occupations, including occupations that require a high level of knowledge from science, or related fields and experience gained through at least one year of on-the-job-training, including repairs, maintenance, food preparations, construction, production, forestry, etc. [22]. For example, while a sales manager is viewed as a non-science related occupation, it can be science-related in the sense that the occupation holder benefits from this field in terms of competences (skills, knowledge, attitudes, and values), especially when working in a company that produces laboratory equipment and chemicals, or in an industrial engineering company. Thus, including occupations like sales manager, school headmaster, baker, and others in determining students' SCA can potentially show whether students see the linkage between learning science and other occupations additionally to scientists' or technicians' occupations.

To succeed within a science-related career path, competence in the sciences is needed, along with interpersonal skills like communication, collaboration, and teamwork [23]. More specifically, persons within such a career path are required to be capable of [24]:

- applying and increasing existing theoretical and factual knowledge in the specific field,
- conducting and analyzing research,
- preparing scientific papers and reports,
- conducting experimentation,
- supervising and managing the work of others,
- having interpersonal communication skills,
- having creativity,
- undertaking complex problem solving,
- decision-making based on theoretical and factual knowledge in the specialized field;
- possessing technological skills (product design, production).

Jang [23], in an overview of attributes relevant for STEM career paths puts forward the following competences as the most important for managing work activities—use of logic and reasoning (critical thinking); active listening; written and oral presentation skills, independent work; English language skill; ability to search for information; making decisions and solving problems; interacting with computers; communicating with supervisors, peers, or subordinates and updating and using relevant knowledge. Nonetheless, there is a need to recognize the variations of required competences among different occupations and specific positions in an organization.

1.2. Students' Science-Related Career Awareness

Tai, Lui, Maltese, and Fan [25] pointed out that the majority of students decide their future careers during middle school, while those who indicate an initial interest towards STEM starting from middle school or later, are more likely to complete a STEM major at the tertiary level [26]. This is in line with Gottfredson's theory of circumscription and compromise [16] proclaiming that those in adolescence, aged 9–14, have reached the stage in their cognitive development where they can portray occupations for themselves. Moreover, adolescents start to eliminate career options, based both on their self-evaluation of internal factors, such as their interests, values, and abilities, as well as external factors, like the status of occupations, expectations of others, and gender-stereotypical images of occupations (*Ibid.*). This suggests that when students hold an image of a science-related career, which does not align with their desired perception of themselves, it is excluded from the pool of options. It also suggests the need to emphasize the importance of educating elementary and middle school students on science-related occupations so as to avoid excluding this career field based on misconceptions or a lack of awareness.

Recent studies demonstrated that middle school students show limited awareness of the mathematics and science requirements for several science-related careers [27,28]. Furthermore, Franz-Odentaal et al. [27] found this limited awareness led to misconceptions such that the majority of students thought engineers "build things". While students indicate that they want a career that is creative and connected with people [10,28], these are not considered as characteristics of science-related careers [20,29].

1.3. Interventions for Supporting Students' Science-Related Career Awareness and Their Evaluation

Various interventions designed to improve students' awareness of careers in science and related fields through embedding career education into science teaching, tried to impact students' attitudes toward science studies. While some interventions were short, lasting for one learning sequence [18,20,30,31], others have been longer, like a six-week intervention, introduced by Archer, Dewitt, and Dillon [17] to year(s)-long interventions [19,32]. Moreover, while some studies addressed adolescence in middle school [17–20,31], others focused on high school students (e.g., [32]).

A common variable among the previously mentioned studies was their use of a wide range of activities, mostly enabling students' active involvement through:

- self-driven and relevant investigations either about careers, industries, or socially embedded science topics,
- visits, or field trips to industries, universities, or sites under investigation,
- scientists, or other professionals from the fields of technology and engineering coming to schools, and
- career education embeddedness in multi-disciplinary teaching.

All such activities were linked with a greater interest in learning science and mathematics, which in turn supported the choice of studies in science or related fields at the tertiary level [33,34].

1.4. Supporting Students' Career Awareness with Specifically Developed Teaching and Learning Modules

The current study was situated within a European Commission funded international project "Promoting Youth Scientific Career Awareness and its Attractiveness through Multi-stakeholder Cooperation-MultiCo". The project aimed to introduce various science-related careers to students by incorporating career scenarios and work-related activities in science subject teaching using specifically created teaching and learning modules (TLMs).

Scenario-based learning utilizes fundamentals from situated learning theory by Lave and Wenger [35] and the idea of situated cognition [36]. The first proposes that most efficacious learning happens in the context where it is to be used and the latter emphasizes the idea that knowledge is best acquired and understood when it is situated in an original context.

The TLMs used in the current study were in line with the Estonian National Curriculum for Basic School [13] and lasted four to five sequential school lessons (45 min) on average. During the whole intervention period, students:

- designed and made a solar panel for charging their phones,
- visited a lemonade factory, seeing the development and production of various beverages and later undertaking, at school, different experiments associated with the beverages,
- were visited by science-related occupation holders (a civil engineer and a forensic scientist),
- were involved in an oil catastrophe simulation to determine the best solution for cleaning the feathers of swans, covered with oil,
- visited the local environmental education center and were introduced to the importance of customs in stopping the trade of endangered species (cf. [37]).

All of the developed TLMs were aligned with a three-stage model of teaching proposed by Holbrook and Rannikmäe [38] namely:

- contextualization by using a scenario to stimulate student motivation and solicit student ideas,
- de-contextualization to enable learning of conceptual and procedural science knowledge through collaborative, investigative, and hands-on work-related activities, and
- re-contextualization to the scenario to promote socio-scientific decision making plus reflections regarding the scenario context, skills developed in stage 2 and careers introduced during the TLM (cf. [37]).

Placing science topics from the Estonian National Curriculum for Basic School [13] into the context of solving a problem that the electrical engineer or the biochemist in a lemonade factory might face in his/her work, should, therefore, serve a twofold purpose: helping to learn science meaningfully and supporting students' science-related career awareness development.

Authors found that the developed TLMs were perceived by the majority of students as interesting, likeable, and relevant [37]. Moreover, through the module activities, it was easy for most students to relate themselves with the situations in which they were put (*Ibid.*).

Students perceived themselves learning science and developing skills relevant for their future careers, thus indicating support for a situated learning theory [35] and cognition [36].

However, the majority of students considered science-related skills as non-applicable for their future careers [37]. Thus, the focus of the current study was to determine what students did consider as science-related skills and which occupations they considered as science-related as indicators of students' science-related career awareness.

1.5. Evaluating Intervention Effects on Students' Career Awareness

Different strategies have been used to determine intervention effects on students' career awareness. Salonen et al. [18,20] and Tolppanen et al. [31] addressed the effects of interventions on career awareness development through students' self-evaluations about whether students gained new knowledge about science-related careers and whether the necessary set of skills were promoted besides the skill applicability to their future studies and future professions. Findings showed that, although students became more knowledgeable about different careers, students did not find the introduced careers suitable for themselves and also, the skills related to the introduced careers were not valuable for their future careers.

These findings were similar to those from project ASPIRES [17] in the sense that students:

- named a wider variety of occupations as science-related after the intervention, which gave an indication of broadening views,
- became more positively minded about science applicability;
- however, the overall aspirations toward science careers did not change.

Also, in the study conducted by Fouad [19], awareness gain about science-related careers, related to duties and attributes, together with the positive effects of the intervention on students' high school choices, were reported.

1.6. Concept Mapping as an Assessment Tool

As this study was part of a larger project MultiCo, where other variables like attitudes toward learning science and career aspirations were researched with written questionnaires, a different research method was used for determining students' career awareness. The use of a different approach was supported by observations in the classrooms, where students made comments expressing reluctance to answering written questionnaires.

To avoid respondent fatigue among students [39] visual mapping tools like mind mapping and concept mapping were considered. These methods required someone to actively engage in a mapping process both verbally and pictorially [40]. Thus, it was expected that by using visual mapping tools, which were more creative in nature, students would be more motivated to participate.

Visual mapping tools like concept mapping and mind mapping share commonalities like linking between concepts. The main differences between these two methods lie in the essence of the linking words or phrases (either being associative–mind maps or relational–concept maps) and in the layout of the maps (either radial tree-like–mind maps or hierarchical top-down structure–concept maps) [40,41].

The traditional concept map starts from the top with the most general concept and branches downwards in levels of concepts, which become more specific towards the bottom. The concepts are linked together mostly by verbs, but also using other words to form meaningful sentences and propositions [21]. This quality of concept maps makes them a subject for evaluation related to knowledge about a specific topic [21,42].

Three conditions need to be met to consider concept maps (CMs) as an assessment tool [42]:

- a task that invites students to showcase their knowledge structure in a given topic,
- a format, which enables the construction of the CMs,
- a scoring system for accurate and consistent evaluation.

The way students are instructed to construct the CMs has an impact on the outcomes. More specifically, evidence shows that the less students are directed with a predetermined structure of CMs, the more content-rich CMs are developed, based on students' propositional knowledge [43]. Nonetheless, when students are given the freedom to make their own concept maps, they do not necessarily end up with the traditional hierarchical structure (*Ibid.*). Although concept mapping has potential to provide rich data about students' SCA, the validity and reliability of this method as an assessment tool needs to be checked, as discussed most recently by Plotz [44]. In the context of the current study, the issue of validity and reliability has come under discussion, when different results were obtained, using rating scale items in a questionnaire [45], in comparison with concept mapping data analysis results. More specifically, when students were asked to evaluate how important they considered various competences for science-related careers, then the results indicated good awareness (*Ibid.*).

2. Materials and Methods

2.1. Study Design

The study followed a longitudinal, pre-test, post-test design (Stages 1–3, Figure 1). Over a period of three years, five different STEM-related, careers-introducing, teaching and learning modules (TLMs) were implemented by pre-trained science teachers (c.f. [37]) and possible effects on experimental group of students' SCA were determined via the implementation of a questionnaire [45], plus the development of concept maps. The latter is under investigation in the current article. The control group was taught, following the Estonian National Curriculum for Basic Schools [13] and no extra activities for supporting science-related career awareness were implemented. The control group answered to the questionnaire and developed their concept maps in 7th grade and in 9th grade.
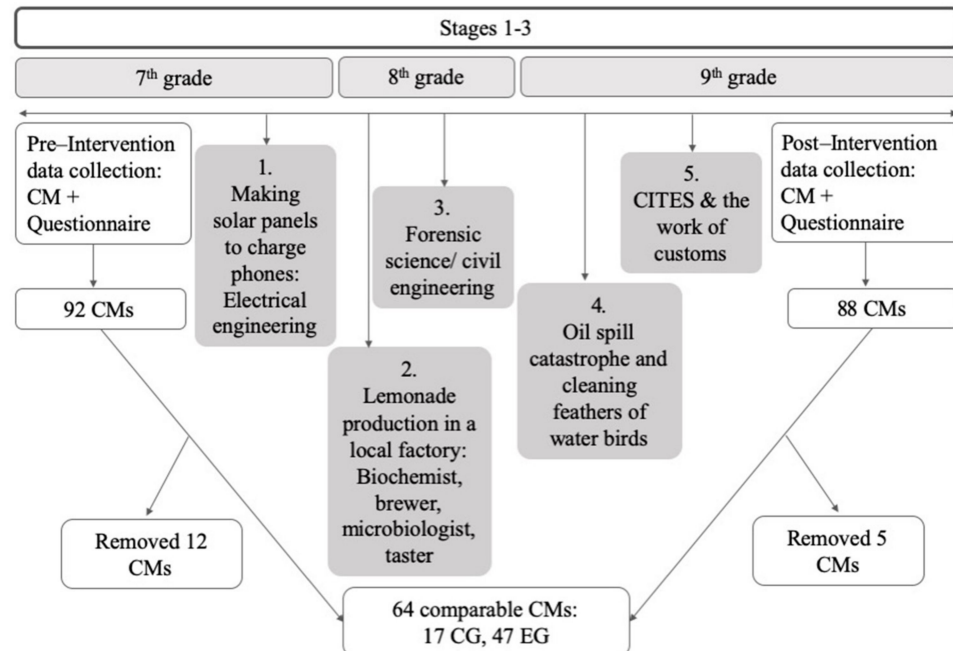

Figure 1. Study design of stages 1–3. Note: CM—concept map, EG—experimental group, CG—control group.

An additional data collection (Stage 4) for determining 7th and 9th-grade non-intervention students' career awareness using concept mapping, in combination with semi-structured focus group interviews, was added for two reasons:

1. to better appreciate students' cognitive processes behind the development of concept maps;
2. to provide additional validity and reliability for interpreting concept maps.

The additional students' group (later referred to as AG) did not receive any additional science-related career awareness supportive intervention, but they were from one of the intervention schools. Although including additional students' group from grades 7 and 9, would not show the progress of the same students, it can indicate the potential increase in career awareness, within the three years.

This is supported by the Estonian National Curriculum for Basic School [13], which includes supporting students' science-related career awareness development as an educational goal in all science subjects (biology, chemistry, physics, and geography).

2.2. Sample

The intervention was conducted in three different Estonian public schools (N = 82, 43% girls). One additional class of students from a separate public school served as a control group (N = 25, 60% girls). All the participating students were from schools, where the teaching language was Estonian, and their socio-economic background were similar.

The concept mapping for stages 1–3 was completed by 92 students in 7th grade, and 88 students in 9th grade. The preliminary analysis detected that 12 and 5 CMs accordingly had to be removed from the 7th- and 9th-grade data pool, due to lacking connections with the central term. Comparative data of pre- and post-intervention concept maps was collected from 47 students (38% girls) and 17 students (53% girls) from the experimental and control group accordingly.

An additional sample of students (AG) was created to form a stage 4, post-intervention. The AG group developed concept maps and this was followed by focus group interviews. The AG (37 students, 17 from the 7th grade and 20 from the 9th grade) was drawn from 2 sets of 7th and 9th grade students but were not involved in the intervention stages 1–3.

2.3. Research Instruments

Two sets of instruments were used for both the EG and CG to determine the possible changes in students' SCA: a questionnaire with rating scale items [45] and concept mapping. With the results from the questionnaire serving as a discussion reference, the following paragraphs focus on devising concept maps and an instrument for semi-structured focus group interviews.

2.3.1. Undertaking Concept Mapping

The concept mapping approach employed, used pre-inserted concepts (occupations and competences) supplied to students (see Appendix A, Figure A1) within the IHMC *Cmap Tools Cloud* application. For this, students were presented with a list of 22 occupations and 18 competences in the 7th grade and the same 22 occupations with 20 competences in the 9th grade.

The list of occupations was based on occupations introduced in the intervention TLMs. Nevertheless, as the teaching of science in Estonia is via separate subjects (biology, chemistry, physics, and geography), it was considered justified to include additional occupations related to each separate subject.

The list of competences was derived from ISCO-08 [24] as descriptions of science and engineering major occupation groups and from research by Jang [23].

Two competences, specifically 'lifelong learning' and 'directing/teaching others', were added to the post-intervention concept mapping list of concepts, based on earlier findings [45], which identified students' low level of aspirations toward teaching professions prior to the intervention.

2.3.2. Semi-Structured Focus Group Interviews

Semi-structured focus group interviews were implemented in the 4th stage with an additional group of students (AG), who had not participated in the intervention, but undertook concept mapping. Students were asked the following questions about their CMs:

1. On the scale of 1–5, how easy, or difficult was it to create your concept maps?

2. Indicate whether there were any unknown concepts?
3. On the scale of 1–5, how do you rate your science-related career awareness (SCA)?
4. How well do you feel the CMs showcase your SCA?
5. How did you interpret the term 'science-related occupation'?
6. How was it seen as different from a 'non-science-related occupation'?
7. How did you decide which competences to select in your CMs?
8. If you could change anything in your CMs, what would it be?

2.4. Data Collection

Concept mapping was administered to the students by one of the researchers, both prior and after the intervention. In this, students were asked to develop CMs using the IHMC *Cmap Tools Cloud* application. Although students were familiar with the concept mapping, it was new to draw concept maps by using that specific cloud application. Therefore, a demonstration on how to use the application was conducted before data collection. The necessity to use additional linking words, or phrases to conduct propositions as meaningful sentences was emphasized. The demonstration lasted five to ten minutes, depending on whether students had any questions.

Students were asked to use the concepts given in the application, without any layout restrictions and answer the following focus questions:

1. Which occupations, in your opinion, are related to science?
2. Select competences (skills and knowledge) which you feel are needed for the occupations selected, within the science-related career path?

Students in all groups (EG; CG; AG) constructed the CMs during one school lesson (45 min) and they were given the chance to modify their CMs during the following week. (Although they had the opportunity, no student availed themselves for this). One girl's (from 7th grade) finished CM is provided as an example in the Appendix B, Figure A2.

The semi-structured focus group interviews were guided by the same researcher as in the main study. The interviews were conducted with the AG in small groups of 3–5 students and lasted fifteen minutes on average. The interviews were voice-recorded and transcribed.

The participation in the intervention and concept mapping for all students was voluntary and based on the consent of the participating students and their parents. Students' privacy was protected by coding the names and analysis was conducted without attached names. The data was stored on one of the university computers and accessible only with a password.

2.5. Data Analysis

2.5.1. Concept Mapping Data Analysis

The pre-inserted list of occupations and competences, which were selected by students on their CMs, was inserted into an Excel file and dummy coded (1 concept present, 0 concepts absent). Both 'sum of occupation concepts used' and 'sum of competences concepts used' were calculated to determine the progression of SCA.

An IBM SPSS Wilcoxon Signed Rank test with exact significance (2-tailed) was utilized for detecting changes in the amounts of concepts used prior and after the intervention. For this, the two added competences concepts ('life-long learning' and 'directing and teaching others') were removed so as to provide comparability between the 7th- and the 9th-grade results.

A Mann–Whitney U-test, with exact significance (2-tailed), was used to determine differences among groups. The comparability of the additional non-intervention students' group and the intervention sample from the same school was checked with Mann–Whitney U-test, showing no differences at 7th grade ($p > 0.05$), which indicated that students´ SCA was similar in 7th grade.

2.5.2. An Analysis of Semi-Structured Focus Group Interviews

The semi-structured interviews were analyzed, question by question, using inductive coding, and overall themes were developed, based on the derived codes. The initial analysis, with coding and forming themes, was undertaken by the first author and discussed with other authors to form consensual themes, which could best describe the findings. A summative approach was taken for providing an easily comprehended overview of the prevalence of themes. Examples of students' responses provided here use code-names, alongside gender and age.

2.6. Validation

An international expert's opinion was sought to determine the comprehensiveness of the provided competences with respect to the global trends of relevant competences for the 21st century working life, with the focus on STEM fields. The expert had extensive experience in science education research at a national and global level, in addition to being highly aware of global trends in education overall and in science education specifically.

The expert analyzed the list of competences from the perspective of two frameworks: 'Definition and Selection of Key Competencies' (DeSeCo) by OECD [46] and 'Definition of 21st Century Skills' by Binkley et al. [47].

The expert concluded that the listed competences included international views related to the competences needed in adult life, including working life and that the list of occupations included were considered as typical science-related occupations, excluding careers in the health sector.

Interpretive validity was provided with including an additional group of students (AG), who were from one of the intervention schools and matched the age group of the intervention students. These students did not participate in any specifically developed program to support their SCA development.

3. Results

The results are provided in two sections: (a) the comparative data analysis results for all groups (EG, CG, and AG), aiming to determine the effects of the intervention on students' SCA and (b) interview outcomes utilized to validate concept mapping results from the AG.

3.1. Students Awareness of Science-Related Occupations

The differences in 7th and 9th grade students´ awareness of STEM occupations are visible on Figure 2.

All the given occupations were considered as science-related by at least some students among the EG in both 7th and 9th grade. The biochemist and geologist occupations were considered as science-related by the vast majority of students (89 and 94%, respectfully) in 7th grade among the EG, but the biochemist became the occupation, which was considered as science-related by all EG students in 9th grade.

The CG students started with fewer occupations they considered as science-related in comparison to the experimental group (EG) in the 7th grade and did not consider construction worker, sales manager, school principal, journalist, brewer, secretary as a science-related occupation. However, these occupations (except secretary), were considered as science-related in the 9th grade by at least one student among the CG.

All the CG students considered biochemist, environmental specialist, and microbiologist occupation as science-related in 7th grade, whereas these occupations were considered as science-related by fewer students in 9th grade.
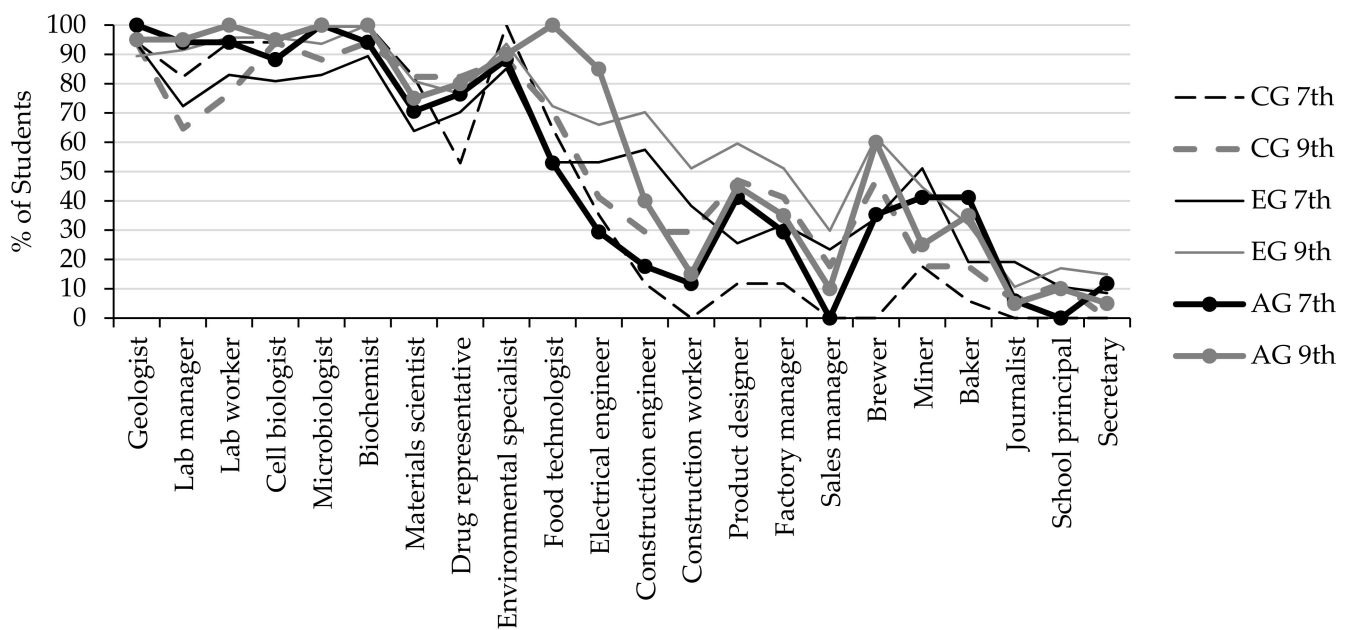
Figure 2. Occupations considered as science-related among 7th and 9th grade students. *Note:* CG—control group (N = 17), EG—experimental group (N = 47), AG—additional students group (N_{7th} = 17, N_{9th} = 20). Datapoints are connected for illustrative purposes.

The additional student group (AG) and the CG were similar in indicating students career awareness, in terms of not considering the sales manager and school principal as a science-related occupation in 7th grade. However, in 9th grade, at least one student considered these occupations as science-related among the AG.

The vast majority of the AG students, among both 7th and 9th grade, considered geologist, lab manager, lab worker, cell biologist, microbiologist, biochemist, and environmental specialist as science-related (all 88% or more).

3.2. Competences Considered Relevant for Science-Related Occupations

An analysis of students' CMs showed low awareness of relevant competences for science-related occupations among both the CG and the EG in the 7th grade (Figure 3). 'Scientific knowledge' was the most used competence among both groups in grades 7 and 9, reaching the highest for the EG in the 9th grade (31%).

The use of competences was noticeably higher among the AG, compared with the other two groups. The 7th grade AG students used 'evidence-based decisions' the most, whereas 9th grade students, similarly to the EG and CG, used 'scientific knowledge' the most (56%).

While 'technological skills' was the least used competence among CG in grade 7 and 9, it became noticeably more used among the EG students. Even so, 'technological skills' was the least used among the EG students in 7th grade, but became more used than 'computer skills', 'creativity', 'foreign language', 'initiative', and 'leadership' in the 9th grade.

Similar to the results by the CG, 'technological skills' together with 'leadership skills', were the least used competences among the AG in both grades 7 and 9.

3.3. Gender Differences in the Progression of Career Awareness

Gender differences were detected in the progress of SCA in terms of both science-related occupations and relevant competences for science-related careers (Table 1).
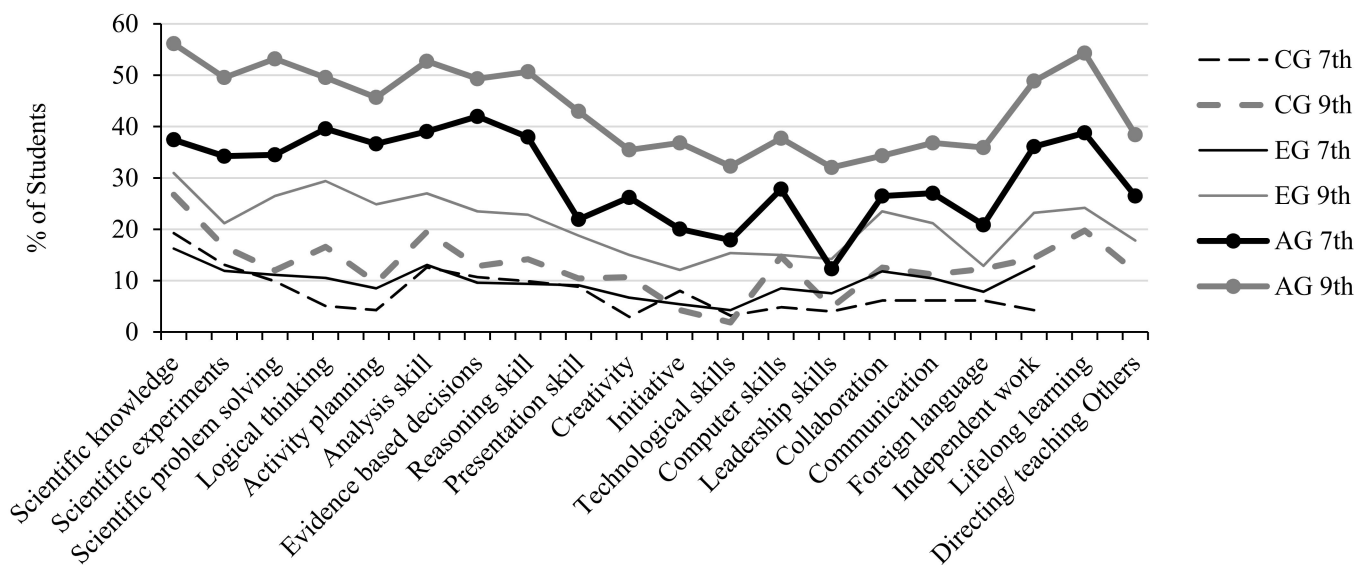
Figure 3. Competences considered relevant for science-related careers among 7th and 9th grade students. *Note:* CG—control group (N = 17), EG—experimental group (N = 47), AG—additional students group (N_{7th} = 17, N_{9th} = 20). Datapoints are connected for illustrative purposes.

More specifically, a significant increase in the awareness of science-related occupations, was detected among both the EG boys (Z = −2.52, *p* = 0.012, ES = −0.33) and girls (Z = −2.91, *p* = 0.002, ES = −0.49). Girls SCA increased from considering 12 occupations to 16 on average (min = 10, max = 21) and boys from 11 to 13 (min = 5, max = 22). Significant increase among EG from grades 7 and 9 was found in the use of competences among both girls (Z = −3.90, *p* = 0.016, ES = −0.65) and boys (Z = −2.37, *p* < 0.001, ES = −0.31) among the EG.

The CG girls' awareness increased from using 9 occupations to 13 occupations on average from the 7th to 9th grade (Z = −2.08, *p* = 0.039, ES = −0.49), whereas 10 occupations on average were considered as science-related among boys in both 7th and 9th grade (min = 7, max = 11, *p* = 0.80). Moreover, a significant growth in SCA was detected among the CG girls in terms of relevant competences (Z = −2.43, *p* = 0.012, ES = −0.57), but not among the CG boys (*p* = 0.74).

The analysis of CMs from AG showed no statistically significant differences in SCA between 7th and 9th grade girls (Table 2). Significant differences were found between 7th and 9th grade boys in the use of occupation concepts (Z = −2,78, *p* = 0.005, ES = 0.41) and competences concepts (Z = −1.995, *p* = 0.050, ES = 0.21) indicating that 9th grade boys were considerably more aware about science−related occupations and relevant competences in comparison to 7th grade boys among AG.

Table 1. Changes in students' science-related career awareness (SCA).

		Control Group (CG)														
		Boys								**Girls**						
	Variables	**N**	*M*	**Min**	**Max**	**Pos (%)**	**Neg (%)**	**Z**	**ES**	**N**	*M*	**Min**	**Max**	**Pos (%)**	**Neg (%)**	**Z**	**ES**
Occup.	Pre / Post	8	10 / 10	6 / 7	14 / 11	4 (50)	3 (38)	−0.34	−0.085	9	9 / 13	7 / 6	11 / 17	7 (78)	2 (22)	−2.08 [a]	−0.49
Comp.	Pre / Post/+Added 2		36 / 21/22	2 / 10/11	130 / 26/30	4 (50)	4 (50)	0.67	0.17		26 / 75/87	12 / 7/7	68 / 198/226	8 (89)	1 (11)	−2.43 [a]	−0.57
		Experimental group (EG)														
Occup.	Pre / Post	29	11 / 13	5 / 5	22 / 22	20 (69)	6 (21)	−2.52 [b]	−0.33	18	12 / 16	7 / 10	18 / 21	12 (67)	4 (22)	−2.91 [b]	−0.49
Comp.	Pre / Post/+Added 2		36 / 91/102	5 / 3/3	176 / 396/440	24 (83)	5 (17)	−2.37 [a]	−0.31		54 / 70/77	6 / 8/9	256 / 269/300	13 (72)	5 (28)	−3.90 [b]	−0.65

Note: Occup.—occupation concepts used, Comp.—competences concepts used, *M*—mean, Min/Max—minimum/maximum use of concepts, Pos/Neg—Positive/negative ranks, Z—Wilcoxon signed rank test, +Added 2—added competences 'lifelong learning' and 'directing/teaching others', ES—effect size $= Z/(\sqrt{N_{observations}})$. [a] $p < 0.05$, [b] $p < 0.01$.

Table 2. Comparison between 7th and 9th grade students' SCA from additional students' group (AG).

Variables	**Grade**	**Boys**					**Girls**				
		N	*M*	**Min**	**Max**	**Grade Dif.**	**N**	*M*	**Min**	**Max**	**Grade Dif.**
Occup.	7	8	10	7	14	Z = −2,78; p = 0.005, ES = 0.41	9	12	6	17	Z = −0.22; p = 0.86, ES = 0.003
	9	12	15	12	17		8	12	8	21	
Comp.	7		122	0	213	Z = −1.995; p = 0.050, ES = 0.21		147	13	271	Z = −0.32; p = 0.75, ES = 0.006
	9		224	41	358			188	104	337	

Note: Occup.—occupation concepts used, Comp.—competences concepts used, *M*—mean, Min/Max—minimum/maximum use of concepts, Z—Mann–Whitney U-test, ES—effect size = $(Z^2/(N-1))$.

Further analysis between the EG and AG 9th-grade students aimed to detect whether the intervention had a greater impact on students' SCA in comparison to regular teaching undertaken in one of the intervention schools. It was found that SCA was similar among the EG and AG boys in terms of both science-related occupations and competences.

However, the EG 9th grade girls were significantly more aware of science-related occupations (Z = −2.445, *p* = 0.01, ES = 0.50), whereas the AG girls were significantly more aware about the relevant competences (Z = 2.13, *p* = 0.03, ES = 0.38).

3.4. The AG Students' Interpretations of Science-Related Occupations and Interpretation Differences from Non-Science-Related Occupations

In the focus group interviews, students from AG included various aspects in their interpretations of science-related occupations (Table 3). Most often, students approached it through 'weighing' how much science, in their view, was being used in an occupation, or whether scientific knowledge was essential for succeeding in an occupation.

To give an example, one group of boys from the 9th grade discussed as follows:

D: *"For example, a secretary for me is not science-related. He/she might work in this field, like assist someone, who does work in the field, but mostly not".* **J**: *"Like every occupation might have the skill, but it is not essential for that [secretary]".*

Interviewer: *"For which occupations are science skills irrelevant?"*

D: *"For example like a school principal does not need science, or a construction worker, or construction engineer. They do not need experience in science."*

U: *"Here I would say, that construction engineering is tightly linked with physics and everything provided here [on concept maps] are connected to the subject. For all electrical engineers, cell biologists, you can find the link. Also, for a brewer, all the fermentation—it is chemistry and biology. But the line for me goes from the school principal and secretary because, in everyday situations, they do not use science."*

Interviewer: *"Are there any conditions, which might make you consider them as science-related occupations?"*

U: *"Maybe. For example, journalist, if he/she is specialized as a nature journalist. But in most cases no."*

The second most mentioned aspect, which students were considering, was research relatedness—either student considered laboratory, various scientists, or making research. As one girl from 7th grade (K) described:

"Just when we started with this task, lab and lab workers came to my mind".

It was almost as common to consider the linkage between science-related occupations and science disciplines, which students were familiar with from the school subjects—biology, chemistry, geography, and physics.

One student added mathematics also to the rest and explained himself (U, 9th grade):

" . . . Mathematics is also a science subject, it is so closely linked with others, fundamental for the rest."

Some students derived their interpretation directly from the word 'natural science' and considered nature-, or environment-related occupations.

3.5. The AG Students' Decision Process While Considering Competences Relevant for Science-Related Occupations

Students' answers represented two ways of thinking about the competences relevant for science-related occupations:

- either they considered competences for all occupations (N = 11)
- or differentiating competences as more or less suitable for one, or the other occupation (N = 22) (Table 4).

Table 3. The AG students' interpretations of science-related or non-science-related occupations.

	Students' Interpretation Categories					
	Extent of Relatedness		Connected with Nature and/or Environment	Connected with Research/Researchers /Lab/Professors	Connected with Science Disciplines	Special Characteristics of Science-Related Occupations
	(a) through Scientific Knowledge	(b) through Using Science				
N	10	10	4	8	7	1
Examples	**Boy 7th grade (G):***"They are all linked somehow. For example, when they need to know something from science."*	**Girl 9th grade (M)**: *"I think that science-related careers are these, for which you need to constantly use field specific knowledge and put it to practice and you are more connected with it. Maybe other people are not so connected with physics and chemistry on every day bases."*	**Girl 9th grade (S):** *"Hmm, one part is connected with the environment"*	**Boy 7th grade (M):** *"Researchers link with the term"*	**Girl 9th grade (G)**: *"Occupations, which are related with chemistry, physics, geology, and all those sciences."*	**Girl 9th grade (V)**: *"It is more like a scientific occupation, not so creative. Like every answer needs to be reasoned. A lot of analysis and stuff like that."*

Note: N represents the frequency students used these categories for explaining their interpretations.

Table 4. The AG students' decision process, while considering relevant competences for science-related occupations.

	Competences for all Occupations	All the Occupations Need the Skills, But Knowledge Needs are Different	Differentiating Competences More or Less Suitable for One or the Other Occupation
N	11	4	22
Examples	**Girl 9th grade (M):***"All of these are very general skills, and everyone needs them in some ways."*	**Boy 9th grade (U):***"Knowledge is specific, like a cell biologist does not necessarily need to be competent in physics, but the characteristics presented here, like scientific knowledge, communication etc., these are general skills for all workers, independent of where you work."*	**Boy 7th grade (H):***"A miner does not need reasoning skills, but for example a cell biologist, when he/she discovers something then he/she needs to reason, why something is the way it is."* **Girl 9th grade (T):** *"It depends on the occupation. Like, for example, a lab manager needs leadership skills, but no one else needs it. Like a food technologist, when he/she is working under someone else's supervision, then it is unnecessary."*

One group of boys (N = 4) from 9th grade specified, that all the occupations need the skills, but knowledge needs are different.

3.6. The AG Students' Self-Evaluation of their SCA

Students were quite modest about their SCA (Table 5). Almost half of the students considered their career awareness being on an average level (rating it '3') or lower. As one girl from 7th grade described it:

> **E1:** *"I have not delved that deep, so the main ones are known, but if one goes deeply into science, then there are so many fields. So yes, I have not delved. But I know the basic ones. Like for example, what is the difference between geologist and botanist? But overall I am not very aware."*

Students who claimed their SCA was above 3, reasoned it with interest in the field and with the research they had conducted by themselves about possible careers in science-related fields.

3.7. Familiarity with Occupations and Competences

The majority of the AG students said, that they were familiar with both occupations and competences (24 out of 37), but familiarity did not mean awareness. Some students discussed it further (18 students) and implied that although he/she was familiar with them, he/she did not know, what these professions do (6 students).

As a group of girls from 7th grade indicated:

> **L2:** *"They were familiar, but if I would need to deliberate on what they do, then I could not."*

> **Interviewer:** *"Can you name me specifically, what were these occupations?"*

> **L2:** *"Materials scientist, microbiologist, environmental specialist.*

> **M2:** *"It is easy"* [referring to the environmental specialist].*"*

> **Interviewer to L2:** *"So you do not know exactly, what they are doing? Or how to interpret your answer?"*

> **L2:** *"Like yes, I do not know what they do exactly. I can guess, but I do not know for sure."*

> **T:** *"Like everything presented here, I do not know, what they do exactly, or what they are researching. You can guess by the name, but not exactly."*

> **L2:** *"Drug representative also."*

An additional occupation one student raised was a construction engineer.

A girl from 9th grade was not sure whether it was science-related or not, putting it like this:

> **M3:** *"Construction engineer—I cannot tell if it is or is not science-related. Because he/she does not do science that much, but at the same time he/she could use some physics knowledge and mathematics."*

> **Interviewer:** *"Is mathematics a science discipline?"*

> **M3:** *"I am still not sure. It is not part of the humanities, so it doesn't interest me."*

The question of familiarity of concepts brought out the need to consider the science-relatedness of other occupations among students, like factory manager (2 students), food technologist (3 students), and lab worker (1 student).

Table 5. The AG students' self-evaluation of their SCA.

	Self-Evaluations					
	'1'	**'2'**	**'3' or "Average"**	**'4'**	**'5'**	**Other, Missing Number or between Two Numbers**
N	2	1	16	2	–	16
Examples of reasons	–	Girl 9th grade: *"I'd rather not choose a profession from the science field, and, like, I do not know much about it."*	Boy 9th grade *"Somewhere in the middle. Do not know too much. Three or so"*	Boy 9th grade: *"I would evaluate it like 4 or 5, maybe rather 4, because I have felt my whole life that hard sciences or natural sciences interest me and that is why I have done my own research about it."*		*"Good enough"*, *"Enough"*, 2.9, Girl 9th grade: *"Four or three, because I am interested about it and I have been thinking about studying science a lot, and what I could do with it later in life.*

3.8. Concept Maps as Representations of the AG Students' Science-Related Career Awareness

Although not all interviewed students commented whether the CMs were a representation of their SCA (with two claiming they do not know how well these represent their SCA), approximately 25% of the students (N = 8) considered CMs as a good or rather good representation of their SCA.

As one girl from 7th grade, who rated her SCA as '3', put it:

K1: *"It shows, what I know at the moment, but I could know more."*

Interviewer: *"What could you know more?"*

K1: *"Like overall, some occupations need science, and I do not know about that. And I do not know at all, which occupations could use that knowledge."*

The majority of the responding students (15 out of 25) claimed partial representation of their SCA, reasoning it with lack of possibility to add how and why he/she used these concepts (3 students).

Three students mentioned, that occupation-wise it was a good method, but characteristics-wise, not so good.

Some students indicated the potential to develop the CMs further, by adding extra linking phrases to form fuller sentences or conduct additional research online (2 students). As one girl from 7th grade described:

L1: *"You can choose yourself, which [occupations] could be linked, which characteristics [they have] and what they do. But you could also search the Internet, to find out, is it the way you had thought or is it different, whether something could be added."*

3.9. The Difficulty of Undertaking Concept Mapping

Concept mapping was seen as either rather easy, or rather difficult, for the majority of the AG students (27 students out of 37 said either 2 or 3 on the scale of 1–5). The most mentioned reason for feeling the difficulty was due to the need for thinking (8 students) about which occupations were/not science-related, in addition to thinking which competences these different occupations needed.

One girl (L1) from 7th grade put it like this:

"For me, it was like 3-ish, because there were a lot of characteristics, which different people should have and I had to think, which field it goes to and which characteristics are the most needed."

Another aspect of the difficulty, brought out by students, was the thinking range of including, or excluding some occupations. Like the group of girls from 9th grade, were discussing:

G: *"It was difficult. First, you start looking, which [occupations] are science-related, but then you look and see that every occupation has to be considered as science-related."*

M1: *"Yes, it depends on how wide or narrow is your thinking".*

G: *"And you can add sales manager as a science-related occupation. It just depends on the field."*

M1: *"Yes, it depends on what he/she is selling, like some are loosely linked and some are directly linked, depends on the conditions."*

G: *"Construction worker one day is, and another day, is not."*

Two students indicated problems with the concept mapping program, which had contributed to their feelings of difficulty with the process.

3.10. What Would the AG Students Change in Their Concept Maps?

The majority of students (24 out of 37) did not want to change anything in their CMs. The students who claimed that they would like to change something, would either

add more competences and/or more occupations (N = 4) in their CMs, or would add explanations (N = 3).

One girl from 7th grade (L1) explained herself:

"I would add more competences to a miner and for a geologist. For example, leadership skills and activity planning. They have to think, how to act to avoid the cave from collapsing."

The majority of the students did not mention lacking time. However, 6 students mentioned running out of time.

As one boy from 7th grade put it: "There was too little time to make it thoroughly".

4. Discussion

The focus for the current study was seen as exploring the effects of implementing TLMs, which included information and work-related tasks of science-related occupations, on students' SCA. As the TLMs were aimed toward introducing various science-related occupations and developing competences needed in these fields, then these two aspects were assessed utilizing concept mapping.

Although the study sample was small, it was found that students' SCA development was supported by the intervention. This meant that more students, both boys and girls, saw the linkage between various occupations and science after the intervention, in comparison with the control group. In addition to considering various natural scientists, like geologist, microbiologist, biochemist, and laboratory workers as science-related careers, more students considered brewer, baker, and engineer as also science-related. This finding was similar to other interventions investigating science-related career awareness [17,18,20,31] and showed the broadening of students' SCA when career education was implemented in science teaching.

The intervention also supported students' awareness development regarding various competences, relevant for science-related careers. Competences were deliberately chosen to cover those needed for all workers in the current era [48], in addition to science field-specific competences. Jang [23] emphasized that there was a need, among tertiary students, to develop science field-specific competences beyond 21st-century skills [47]. The authors of the current article in agreeing with this need, perceived the need to show (among middle school students) that science was not just about scientific knowledge, experimenting and analyzing. Moreover, the intervention induced growth in recognizing the relevance of technological skills (design and production) for science-related careers. This finding was supported by further results that showed that the experimental group students rated technological skills as relevant in the post questionnaire, whereas the control group did not [45]. This was seen as an indication about acknowledging the importance of technological skills for science-related careers due to participation in the intervention.

Although the concept mapping technique showed there were gains in students SCA due to the intervention, it was noted that concept mapping results could have been better. When students rated the importance of competences for science-related careers proposed by the International Labour Organisation [24] and by Jang [23] for science-related careers before MultiCo intervention in Estonia, students gave high ratings and considered almost all as relevant (excluding technological skills among the CG) [45]. Based on this finding, it was expected that students would use these competences also in their concept maps. Nonetheless, this did not happen, raising the question, what might have caused this discrepancy and was the concept mapping technique a valid and reliable method to use for determining students' SCA.

One of the possible reasons why the results obtained with the rating scale type of questionnaire and the concept mapping did not match could be related with the different nature of the instruments and the level of cognitive function it demanded from the responding persons.

The rating scale items were easy to answer, because the student needed to think about one aspect at a time, e.g., whether the given competence is important for science-related

careers or not. Concept mapping, however, was noted as cognitively demanding [21]. When drawing concept maps, a student was required to think initially about which concepts to use, how they were related with the rest of the concepts, and also where to position the concepts on the mapping area. This explanation gained support from interview outcomes, where students claimed that they needed to think about several things before including concepts in their CMs. Moreover, students claimed being confused about how wide, or narrow they should think, so as to meet the task requirements.

Students' cognitive processes, while constructing CMs, seemed to be influenced by what was familiar from science classes. This was suggested, because the choice of either considering an occupation as science-related or not, was undertaken by:

(a) whether the given occupations needed to use scientific knowledge;
(b) whether the occupations belonged to science disciplines like biology, chemistry, physics, and geography; or
(c) whether the occupations were associated with the use of laboratories, or with nature.

Moreover, the majority of the students claimed they had chosen to use occupations which they thought were the most related with science, but some recognized, in the interviews, that they saw the linkage with wider range of occupations.

While considering which competences to include in their concept maps, the majority of students indicated naïve ways of thinking: that is, the students differentiated the relevance of competences with respect to one or another occupation rather than considering competences relevant for all. This was seen as an indication of low awareness of the range of competences needed within a career.

The interviewed students evaluated their career awareness in science-related fields to be rather modest. But it became evident from the interviews that students who were interested in science had researched possible careers independently, thus supporting their career awareness in science-related fields. Nevertheless, the majority of students were aware of the most common and traditional occupations in science-related fields, like scientists and laboratory workers, but many had self-doubts about the relatedness of engineering to science and whether mathematics and physics could be considered as a part of science. This was similar to the findings reported by Blotnicky et al. [28]. It supported the need to include career-related information within science teaching in a meaningful way, thus supporting students' conceptual awareness about various science fields, their areas of overlap, possible career outcomes, and the applicability of science and mathematics competences in various occupations.

The Suitability of the Concept Mapping Technique for Evaluating SCA

Prior studies mostly implemented questionnaires for researching students' SCA [17,18,20,31]. This was not considered an option for the current study, because questionnaires were used for determining intervention effects on students' attitudes towards TLMs, towards studying science, and towards science-related careers [37]. In an attempt to avoid respondents' fatigue among students, a more novel method was introduced to determine changes in students' SCA. Thus, concept mapping was implemented noting its potential to engage respondents both verbally and pictorially [40] and thus be more motivating in comparison with filling in a questionnaire.

Concept mapping is known for its hierarchical top-down structure, where concepts are linked with labelled lines to form meaningful statements, the outcome being evaluated [21]. Nonetheless, the hierarchical structure may not be representative of the way knowledge is organized in students' minds and thus any provided structure may restrict students' showcasing their knowledge structure [43].

In the current study, students were given the freedom to construct their maps without specific structural requirements. This resulted in concept maps, which more resembled mind maps, because of their branching from the center, but kept the essence of concept maps, through the inclusion of propositions. Although the structures of the propositions were simple, due to the similar type of concepts provided (occupations and competences), the concept mapping process was still cognitively activating for students.

Concept mapping was seen as a questionable technique in terms of it being a valid evaluation tool for conceptual learning [44]. Therefore, the use of concept map was employed, with the AG group, in combination with interviews so as to validate the outcomes. These outcomes showed that students did hold rather poor awareness of science-related careers and they rated their career awareness as moderate in the interviews. Based on the concurrence of the interview and concept mapping data, it was concluded that in terms of evaluating students' career awareness, through various occupations and relevant competences, the concept mapping technique could provide meaningful outcomes.

5. Conclusions

The current study aimed to determine the impact of a three-year intervention on students´ science-related career awareness. The intervention consisted of implementing five specifically developed teaching and learning modules, which in addition to achieving the goals set in the Estonian National Curriculum for Science content wise, also supported the development of students' science-related career awareness in grades 7–9. The intervention impact on students' SCA was determined with concept mapping technique and it was implemented prior and after the intervention to gain comparable information regarding students´ awareness of science-related occupations and relevant competences.

The results showed that students´ science-related career awareness in terms of awareness of science-related occupations and relevant competences did progress among the experimental group students. The progression was visible for both boys and girls with respect to occupations and competences. This result indicated the effect of incorporating career-scenarios and work-related activities in science subject teaching using specifically created teaching and learning modules that provided equal opportunities for both girls and boys to gain an awareness of science-related careers. Thus, SCA supportive TLMs could help with counterbalancing potential gender difference in students' career aspirations, by showing girls that they were as capable, for example, of electrical engineering as boys, while showing boys that environmental protection and nursing animals, as careers, were not only for girls.

Semi-structured focus group interviews with additional students' group provided similar results with their concept mapping results, which suggested that concept maps enable to represent students' awareness of science-related careers well.

6. Implications

Concept mapping was shown to be a suitable and resourceful method to determine students' career awareness, both for research and as a conversation starter with students.

Concept mapping could be used in science classes by the teachers, requiring students to think about the topic from more than one perspective. Thus, CMs provide both the teachers and students an acknowledgement of students' awareness about science-related careers.

7. Limitations

The authors were aware of possible threats to content validity in terms of including a rather small selection of possible science-related careers and competences due to the risk of overwhelming students with too many concepts. The selection of occupations was driven by the occupations introduced in the intervention and the structure of science teaching in Estonia. Some occupations, which lacked direct indication to science, were considered as justified to use to determine the width of students' thinking. This approach was successful, when concept maps and interviews, were used together.

The intervention lasted three years in total and addressed students in the ages 13–15 years. During this time, maturation was inevitable, and it could be seen from the control group and additional students' group results that some students' SCA progressed even without the intervention. Furthermore, as concept mapping is cognitively activating, the process itself might induce learning, by showing where one lacks knowledge. Therefore,

one could not exclusively derive the growth of students' science-related career awareness from the intervention, as described here.

Institutional Review Board Statement: The Research Ethics Committee of the University of Tartu was consulted with prior to the beginning of this study. The research activities supported the achievement of the goals set in the Estonian National Curriculum for Basic Schools, and thus no ethics committee approval was considered necessary.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The research data used in the current article is available upon request from the corresponding author.

Appendix A

The blank canvas providing concepts (occupations and competences) for students to select from and use for concept mapping is shown in Figure A1.
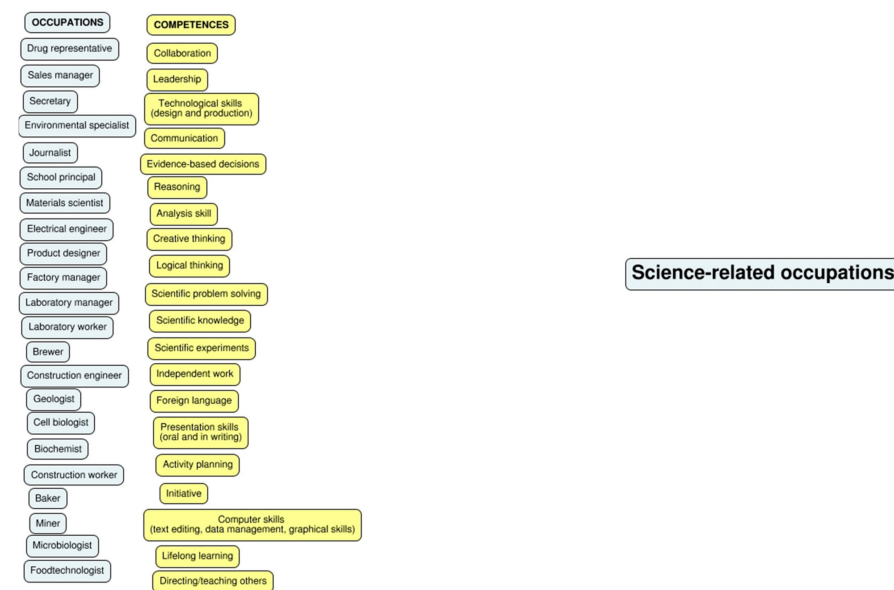

Figure A1. The blank canvas with concepts. *Note:* 'Lifelong learning' and 'Directing/teaching others' was added to the version used in post intervention testing.

Appendix B

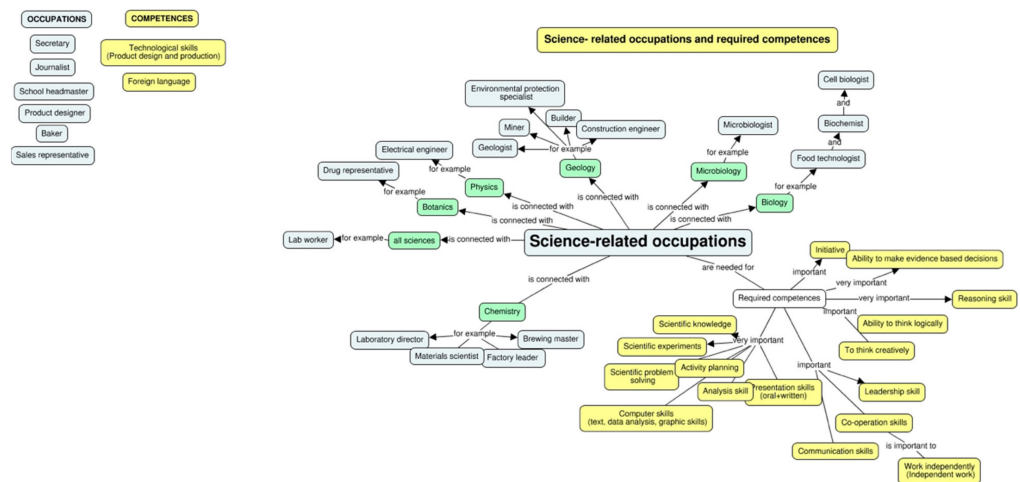One student's finished concept map is shown in Figure A2.

Figure A2. A translated version of one 7th grade girl's CM.

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