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Exploring Competing Perspectives on How to Design Open Innovation Program for High School STEM Education: A Case Study

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Abstract: Open innovation (OI) has become an essential business model for big tech companies and innovation ecosystems. However, most STEM high schools in the United States do not have appropriate OI programs for students. This paper explores how various perspectives on open innovation as an emerging trend in the entrepreneurial ecosystem can link with STEM education programs. We use the Q methodology technique with interviews from students and managers of STEM education at C Academy and academic members from a field of open innovation. Twenty-three participants responded to the 35 Q statements derived from preliminary findings of critical issues on a relationship between open innovation and STEM education. Five key perspectives compete, each with a unique view on why STEM education matters and how to renovate the current STEM program for an open innovation-based curriculum and club activities inside and outside high schools. Empirical findings from Q method analysis combined with Promax rotation illustrate five views: (1) civic virtue-driven open innovation, (2) open innovation with imagination from arts and culture, (3) daily life-based open innovation project, (4) critics on conventional STEM education, and (5) community service-driven open innovation. A common area that all five perspectives support is that the government should expand and strengthen support in the design and operation of open innovation education programs in STEM high schools.

Keywords: STEM; open innovation; Q method

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1. Introduction

The recent STEM education reform fosters creative thinking by creating a multidisciplinary program that combines the arts, humanities, and STEM fields [1–3]. The STEM reform also promotes an entrepreneurial spirit for young scientists who are college graduates [4]. However, the current STEM education in high schools primarily emphasizes excellent academic outcomes by promoting science and technology areas [5]. Further, it appears that STEM talent education prioritizes admission to famous top-level universities [6]. High school STEM curriculums do not provide appropriate programs for students to grow into future innovators after graduation [7]. Even if students go to a top-level university, they have not adequately experienced innovative education through learning collaboration and cooperation from various activities in high school. The lack of innovation experience within the curriculum and practice of STEM high schools may become an obstacle to engage in entrepreneurship after high school.

Recent innovation ecosystem trends emphasize openness and network beyond the limits of the conventional research lab's concealment and silo mentality [8–10]. The contemporary dominant innovation paradigm connects with product platforming, collaborative product design and development, and open science and further entails innovation networks and innovation intermediaries. These innovative approaches represent open innovation

(OI), not closed innovation. OI's rationality suggests that an organization (company) creates a new market by using novel ideas and resources from inside as well as outside [10,11]. The OI principle involves sharing ideas and resources in collaboration with various actors across organizational boundaries [12]. OI's scope does not remain within the company but actively connects with external consumers and communities. Recent big tech companies tend to buy or license various outside ideas [13,14]. They also share their assets through licensing, joint ventures, or spin-offs. These OI activities create new markets beyond organizational boundaries and industrial borders [15].

However, in our opinion, high school STEM education does not adequately reflect the recent trend in emerging innovation and business models. STEM education practices are not well connected with crucial elements of open innovation, linking together outside-in and inside-out resources and ideas in spite of the lower level of resources in schools. Since the learning of various innovative experiences can nurture a young generation's potential innovation capacity, it is crucial to integrate OI's approach with high school STEM education. It might be too late during college to experience the diverse and creative activities needed for a startup. Early education on OI in high school will yield more performance than OI education in college.

This study critically examines high school STEM education from the OI perspective through applying Q methodology. Opinions of stakeholders related to STEM education were collected. Q statements were developed from commentaries of high school students and program managers from C Academy and academicians from a field of open innovation research. Findings suggest five competing viewpoints with one common area. The structure of this paper is as follows. The literature review provides key issues on STEM education and open innovation. The section on methods and data describes Q methodology and the data collection process. The empirical findings section provides five perspectives on how to link open innovation and STEM education. Finally, we discuss policy implications about how to develop OI programs at STEM high schools.

C Academy is a three-year residential magnet public school for students gifted in math and science in Illinois, USA and has been consistently ranked among the top 10 schools in the United States among high schools for math and science.

C Academy provides rigorous college preparatory courses, and all classes are at an honors level, and it also provides a large number of clubs ranging from religious clubs to volunteer organizations. The C Academy curriculum includes math, science, foreign language, English, history, social science, wellness, and fine arts.

Student Inquiry and Research (SIR) at C Academy is a research and internship program for juniors and seniors every Wednesday during the semester. In most scientific fields, SIR is used as a pathway to gain experience in joint research with universities and research institutes. Students at C Academy participating in the SIR program participate as RAs at the nearby research universities and research institutions. Some of the students also participate in business and entrepreneurship programs around the world. Innovation Center (IN2) is a communal idea center that strives to provide students at C Academy with an innovator spirit. Leadership Education and Development (LEAD) is a mandatory program for all new sophomores. LEAD is a student-centered program focusing on providing an opportunity for facilitators through a variety of innovation and leadership programs. The recent STEM education program strives to link academic knowledge and theories with the real world. It aims to improve the new economy and STEM literacy through connections with local communities and businesses.

Nonetheless, there are still apparent limitations in connecting new business models or innovations emerging in the market. It is not easy to find an appropriate program that combines the STEM curriculum with entrepreneurship so that students can practice in the workplace or create startups. Recently, C Academy created the Open Innovation Club as an extracurricular activity for students, but it focuses primarily on OI-related research and participation in academic conferences. It still has not reached the level of curriculum reform

for OI-related startups or business model development. The curriculum and content are not satisfactory in producing future innovators.

C Academy has a competitive atmosphere. Few classes exist to perform tasks or cultivate a spirit of adventure, cooperation, negotiation, and network-related skills necessary for corporate innovation and new market development. It is not easy for students at C Academy to develop leadership and cultivate entrepreneurship through collaboration in the current educational environment.

Overall, students at C Academy lack joint clubs or class activities that cooperate with external companies or community organizations to solve various problems. There are not enough opportunities for classes or internships that can help with startups.

1.1. Emerging Demand for a Dense Link between STEM Education and Innovation Program

The importance of early STEM education for adolescents has recently attracted attention. STEM education needs to provide appropriate education and competencies to the younger generation at an early age. Global companies such as Microsoft and Google also support and stress the importance of STEM education. STEM includes the four disciplines of science, technology, engineering, and mathematics. STEM education also emphasizes problem-solving, creativity, and critical analysis.

Furthermore, STEM emphasizes the ability to collaborate and connect with independent thinking and taking the initiative. Above all, STEM emphasizes communication skills and digital literacy to demonstrate these capabilities virtually. Future STEM education pursues an economic and technological paradigm that emphasizes citizen-participated community innovation and coexistence between humans and nature. The current business environment and labor market demonstrate the importance of social skills and innovator spirit [16]. Social skills such as cooperation, networking, and coordination capabilities are essential for reducing transaction costs and finding and implementing future innovation opportunities in business activities.

Scholars have emphasized that early STEM education can provide a stronger foundation for youth to become better innovators in the future. However, the current STEM high school education highlights grade-oriented achievements and focuses on entering university by acquiring knowledge such as science and mathematics. Many tend to neglect the original meaning of STEM and focus solely on university entrance exams. Most high school STEM education focuses on developing good test-takers. Additionally, while the education and club activities of STEM high schools emphasize teamwork, they still do not adequately teach how to virtually connect resources and information that exist within and outside of various organizations. The latest innovation trend emphasizes open innovation that effectively connects multiple resources and ideas inside and outside the organization. Most recent startups are just growing in this open innovation process.

It is better to receive STEM education earlier to grow into innovators who pursue solving various social problems through open innovation combined with their knowledge. This open innovation education needs to connect virtually with governments, educators, curriculum developers, parents, and education advocacy groups around schools, businesses, and communities. High school STEM education should transform itself so that high students experience and embody open innovation earlier on. High school open innovation education should also transform its role and mission into an early education program that fosters future innovators who will lead the global business ecosystem as social innovators.

1.2. Little Attention to Open Innovation Approach

Open innovation has attracted a lot of attention from both business and education as an emerging innovation trend. The open innovation process allows big tech companies such as Google, Amazon, and Apple to create an entrepreneurial ecosystem. The logic behind open innovation is a key route through which startups become leading global companies. Chesbrough (2003) suggested open innovation as both an inbound innovation process and an outbound innovation process to optimize internal and external ideas and

resources [8]. This open innovation consists of three stages [17]. These steps consist of defining, designing, and implementing the open innovation process. The OI process involves identifying the sources of ideas and resources inside and outside the organization and considering connecting them and effectively utilizing them. This process is a vision of innovation, communication skills, and organizational capacity to put innovation into action. Prototyping, planning, devising measurement metrics, manufacturing reviews, market assessment, and review are essential to organization competence.

An OI process also involves the use of purposive inflows and outflows of ideas and resources to accelerate omniscient innovation [8]. Disruptive innovation comes from a link between the OI process and digital technologies (DTs) and develops radical business models and innovation ecosystems. DTs can play a large role in promoting and nurturing OI. As DTs link with social media, they can effectively utilize the diversity of knowledge, information, and resources. The link between DTs and OI has created a platform of a multi-channel, multi-stakeholder, and multi-stage process [18]. A digitalized OI process provides unprecedented business models and opportunities. However, STEM education does not fully consider these open innovations.

Interest in entrepreneurship education has recently spread [19–21]. Entrepreneurship is cultivated through a variety of new knowledge and experiences. Various entrepreneurial programs seek to provide the knowledge and training experience necessary for innovation in connection with school education. Good entrepreneurship programs contribute to cultivating knowledge and willpower in innovation and entrepreneurship [22]. Many universities have been interested in programs that foster entrepreneurship. More specifically, university-based innovation programs have focused on various business strategies and experiments to provide a catalyst for high-technology startups [23]. Several recent studies have suggested that university entrepreneurship programs influence the formation of entrepreneurship minds among university students. For instance, various club activities in the extra school curriculum may help build an innovative personality [24,25]. One Chinese study examines how innovation education affects students' willingness to innovate among 269 Chinese university students [26]. One Pakistani study examines how relying on 348 Pakistani graduate students' data shows how higher accessibility to entrepreneurial incubation can increase entrepreneurial intention [27]. However, it is difficult to find research on how education programs at STEM schools affect entrepreneurship and innovation. More research needs to explore relevant cases or empirical studies analyzing how high school STEM education can cultivate entrepreneurship and innovation.

Overall, few places in STEM education introduce and teach open innovation courses [1]. Most STEM education programs provide field experience through two pathways. First, students obtain knowledge as young researchers while working as interns in the labs of universities or research institutes in science and technology. The other is to involve business experience indirectly while doing business internships at the company. The problem is that young people in STEM education cannot experience various entrepreneurial skills related to open innovation through actual startups. It is not easy to accumulate authentic experience thinking or practicing how the younger generation will integrate diverse knowledge and information inside and outside high schools. This study aims to identify varying perspectives on open innovation and analyze their relationship to STEM education.

2. Materials and Methods

2.1. Abductive Reasoning Process

This study explores Q factors derived from abductive reasoning from various observed statements and stories from the literature, media documents, and stakeholders. The Q methodology provides researchers with an opportunity to find something unobserved that requires an explanation. The unique and hidden views in current research allow researchers to develop a proposition with a hunch for a plausible explanation. The distinctive findings provide an opportunity to conduct critical debates and further empirical inquiries, which lead to hypothesis generation. The Q methodology also allows researchers to explore

complicated problem areas without the impact of pre-existing theoretical perspectives and conceptual frameworks. This study explores what key issues are from the various subjective perspectives on STEM education and OI. This approach develops potential hypotheses on the relationship between STEM education and OI, using anecdotal evidence, expert statements, and literature review through abductive reasoning. Q methodology demonstrates this abductive approach well. Q methodology represents the systematic study of subjectivity. The detailed Q methodology used in this study is as follows.

2.2. Q Methodology Process

Q methodology involves three components: (1) exploring diverse viewpoints and stakeholders, (2) creating Q statements, and (3) conducting a Q survey and discovering distinct factors from the survey participants. We used STATA program (qfactor) to explore the salient viewpoints of the survey respondents.

The first stage is to develop various statements on how STEM education and OI are connected and how they should interact. These statements are related to a positive or negative stance on how well the current STEM curriculum connects and educates OI characteristics. Additionally, these perspectives will differ depending on the positive or critical attitude toward contemporary STEM education. Furthermore, these various perspectives would be diverse across different opinions on innovating STEM education in the future. The initial questions about the multiple relationships between STEM education and OI can identify these conflicting or competing views.

This stage is to find how various stakeholders think about STEM education and a relationship between STEM education and OI. We used Q methodology to explore multiple stakeholders' perspectives in promoting open innovation education for STEM in the USA. The Q method approach displays how various stakeholders think about open innovation programs in STEM schools. It provides a deeper understanding of STEM and open innovation, especially applying open innovation for STEM education.

The second stage is to design the frame of Q statements. We conducted semi-structured interviews with different types of questions about developing open innovation programs and collaborating with communities and startups outside STEM schools. We selected interviewees from professors and researchers in open innovation to high school students involved in the STEM program. Based on this pilot survey, we introduced 35 Q statements derived from interviews and relevant literature and documents about open innovation programs in the United States' STEM.

Research literature and expert opinions on OI underscore that OI needs to link the community and civic spirit [28]. These views also argue that OI can cultivate imagination and creativity by connecting with culture and art [29]. The recent platform ecosystem requires the connection and imagination inherent in OI [13]. Furthermore, these opinions emphasize that cooperation and networking capabilities are essential because OI must effectively link ideas and resources inside and outside the organization [8,30]. In the recent OI ecosystem, civic spirit, community, and governance are essential, suggesting that STEM education contains culture and artistic imagination [31–33]. These discussions provide a framework for constructing the Q statements of this study.

Our Q method questionnaire consists of 35 statements about open innovation and STEM education. The Q statements come from several interviews with students and program managers of STEM and professors from open innovation research (See Appendix A for a list of statements by five dimensions). The statements are also derived from the literature on open innovation and STEM education. The 35 Q statements include five aspects: (1) 4 statements from various critics of the current status of the open innovation program in STEM schools in the United States (Q1, Q2, Q30, Q31), (2) 8 statements from cultural perspectives emphasizing humanities, imagination, and communication skills (Q15, Q16, Q23), (3) 6 statements from community innovation emphasizing daily life-based projects (Q8, Q34, Q35, Q36), (4) 5 statements from the critics that STEM programs pay more attention to college entrance than diverse, innovative programs (Q3, Q5, Q6, Q12, Q17),

and (5) 7 statements of critical open innovation emphasizing civic virtues and democracy (Q11, Q13, Q18, Q19, Q20, Q21, Q22). Q statements in this study also introduced three perspectives, including (1) artificial intelligence (AI)-based open innovation (Q24, Q25, Q27), (2) open innovation programs coupled with academic conference participation (Q9, Q10), and (3) government support for open innovation programs for STEM (Q6, Q7, Q28).

The third stage is to conduct the survey of Q statements for stakeholders. This Q method survey was conducted from early September to early October 2020. During this period, the questionnaire was sent to the respondents via e-mail along with a Q methodology guide. Participants from high school students and officials at C Academy, professors, and researchers of open innovation were required to sort the 35 Q statements (see Appendix A). We used a 9-point scale from −4 (strongly disagree) to 0 (neutral) to +4 (strongly agree). Here, +4 corresponded to "Agree with most strongly" and −4 to "Disagree with most strongly." Q methodology emphasizes the qualitative "why and how" as stakeholders think about the way they believe or expect, rather than focusing on how many stakeholders have a specific perspective [34,35]. In the Q methodology survey, 32 people initially participated and answered the questionnaire. However, this study used only 23 respondents after excluding inappropriate questionnaires for Q methodology. Most of the inadequate questionnaires were due to the failure to organize respondents' thoughts according to the degree of the pros and cons that the Q methodology follows. We finally used 23 P-sample respondents to conduct various statistical analyses. The P- or "person" sample consists of twenty-three participants. They include 23 actors, including students and innovation program managers from C Academy, researchers and professors in the academic society of open innovation, and business people from startups.

3. Results

Five Views on STEM Education and Open Innovation

The value of factor loading represents the correlation coefficient between observed variables (i.e., individual respondents in Q survey) and common latent factors. A factor loading in the Q methodology shows how an individual respondent is associated with the identified characteristic. A higher factor loading indicates that the respondent's attitude (opinion) is more highly associated with the given factor. A variable's uniqueness is the proportion of variance for the variable not explained by the common elements, representing pure measurement error. The ratio except for the percentage of uniqueness is communality. Tables 1–3 show the detailed statistics for the factor analysis. The factor analysis illustrates five factors with the power to explain 65.5% of the total variance. Factor 1 consists of 25.1% of the total variance. The other four factors represent 40.4% of the total variance, where Factor 2 is 11.4%, Factor 3 is 10.6%, Factor 4 is 10%, and Factor 5 is 8.4%, respectively.

Table 1. Factor analysis (rotation technique = Promax).

Factor	Variance	Proportion
Factor1: Civic virtue-driven open innovation (View1)	5.766	0.251
Factor2: Open innovation with imagination from arts and culture (View2)	2.610	0.114
Factor3: Daily life-based open innovation project (View3)	2.442	0.106
Factor4: Critics of conventional STEM education (View4)	2.297	0.100
Factor5: Community service-driven open innovation (View5)	1.941	0.084
Total	15.056	0.655

Notes: (1) Method: Principal component factors; (2) Rotation: Oblique Promax; (3) Number of respondents = 23 and number of Q statements = 35.

Table 2. Values of factor loadings (rotation = Promax).

Variable	Factor1	Factor2	Factor3	Factor4	Factor5	Uniqueness
Obs 1	0.700	0.018	−0.048	0.138	−0.025	0.475
Obs 2	0.186	−0.595	−0.252	0.260	−0.076	0.501
Obs 3	0.145	−0.625	0.541	0.103	0.272	0.266
Obs 4	0.705	0.133	0.003	−0.086	0.266	0.344
Obs 5	0.235	0.119	0.034	0.013	0.696	0.397
Obs 6	0.161	−0.192	0.011	0.807	−0.133	0.230
Obs 7	−0.100	0.126	0.130	−0.296	−0.604	0.610
Obs 8	0.676	−0.040	−0.006	−0.066	0.328	0.432
Obs 9	−0.181	0.314	0.197	0.746	0.253	0.290
Obs 10	0.269	0.701	−0.060	0.156	−0.076	0.319
Obs 11	0.475	0.527	0.044	0.098	0.056	0.350
Obs 12	0.659	−0.125	0.020	0.013	0.415	0.410
Obs 13	0.854	0.013	−0.147	−0.082	−0.131	0.253
Obs 14	0.676	−0.062	−0.096	0.076	0.240	0.496
Obs 15	0.318	0.081	−0.279	−0.087	−0.052	0.810
Obs 16	−0.174	0.104	0.793	0.035	−0.142	0.369
Obs 17	−0.541	−0.039	0.492	0.262	−0.248	0.386
Obs 18	0.246	0.129	0.745	−0.177	−0.043	0.305
Obs 19	0.761	−0.165	0.375	−0.078	−0.412	0.157
Obs 20	0.468	0.236	−0.412	0.287	−0.276	0.316
Obs 21	0.472	0.190	0.353	0.387	0.088	0.372
Obs 22	−0.126	−0.090	−0.173	0.733	0.294	0.421
Obs 23	0.578	0.389	0.081	−0.163	0.208	0.297

LR-test: Independent vs. saturated: Chi-square (253) = 438.42, Prob > chi 2 < 0.0001.

Table 3. Z-scores and ranks for all Q statements.

Q Statements	Z-Score of Factor1	Z-Score of Factor2	Z-Score of Factor3	Z-Score of Factor4	Z-Score of Factor5
1	−1.23	−0.55	1.22	−0.41	−0.20
2	−1.95	−1.29	−0.55	−0.36	−0.44
3	−1.90	0.09	−0.55	1.42	−1.17
4	−0.15	−1.70	0.85	1.00	−0.69
5	−2.25	−0.21	−0.17	0.11	0.69
6	−1.80	−0.48	0.31	1.28	−1.13
7	0.55	1.17	0.78	0.41	0.48
8	0.47	−0.39	1.09	−1.19	1.03
9	0.75	−1.24	0.72	−1.19	−0.48
10	0.77	−1.26	0.72	−1.24	0.34
11	0.76	−0.09	−0.37	0.58	0.48
12	−1.36	−1.51	−0.61	−0.42	0.58
13	1.25	−0.80	−0.37	1.36	1.13
14	−0.82	0.16	−0.65	1.87	0.82
15	0.02	1.54	0.24	0.27	−0.82
16	0.05	0.50	0.37	−0.67	−0.82
17	−0.09	−0.11	−1.15	−0.32	−0.24
18	0.23	−0.92	−1.26	0.25	−0.24
19	0.96	1.08	−1.94	0.41	0.38
20	−0.08	−0.81	−1.39	1.24	0.44
21	1.20	−0.35	0.48	0.12	−1.03
22	1.35	1.84	−1.46	−0.18	1.41
23	0.14	2.11	−1.39	−0.50	−0.38
24	0.24	0.21	0.61	0.22	−0.62
25	0.24	−0.43	0.92	−1.78	−0.04
26	0.77	−0.28	−0.61	−1.17	1.75

Table 3. *Cont.*

Q Statements	Z-Score of Factor1	Z-Score of Factor2	Z-Score of Factor3	Z-Score of Factor4	Z-Score of Factor5
27	−0.48	0.41	0.00	−2.03	−0.58
28	1.03	0.41	0.48	0.19	0.24
29	−0.78	−0.23	−0.48	−1.09	0.24
30	1.26	−1.47	−0.41	1.48	−1.03
31	−0.76	0.32	−1.02	−1.28	−1.37
32	−0.05	1.31	−0.07	−0.35	−1.75
33	0.30	1.49	1.87	0.35	−1.31
34	0.35	0.83	1.87	0.27	1.99
35	1.03	0.64	1.94	1.36	2.33

Note: Stephenson's formula provided differences between factor scores for each statement.

4. Discussion: Five Perspectives and One Common Statement

4.1. View 1: Civic Virtue-Driven Open Innovation

View 1 is presented in Table 4. In STEM education, open innovation programs should be able to cultivate citizenship. OI must properly teach students the value of collaboration and joint research. Furthermore, if STEM education introduces an open innovation program, it is necessary to clarify why and what it is for. However, most STEM high schools are still unaware of open innovation. This view strongly opposes the claim that there is a lack of motivation for cooperation and collaboration because of competition among students.

Table 4. View 1: Civic virtue-based open innovation.

Q Statements	Z-Score of Factor1
22 STEM education in the open innovation education program must include the citizenship of making a better world.	1.35
30 It seems that most STEM high school students do not know anything about OI yet.	1.26
13 The value of joint research and cooperative research should adequately connect with the STEM high school curriculum.	1.25
21 If open innovation education prevails in STEM high schools, it is first necessary to define why open innovation education is essential and for what.	1.20
35 By promoting open innovation in the form of a project that embodies everyday life around the school, students should experience a sense of accomplishment, providing students with the driving force of open innovation.	1.03
28 Appropriate teacher recruitment and effective education programs are essential for establishing an open innovation program in STEM schools.	1.03
1 STEM high school curriculum and programs do not adequately reflect the concept of Open Innovation (OI) to cultivate future entrepreneurship and venture leaders.	−1.23
12 Due to the nature of STEM high schools that focus on gifted education, individual competencies such as individual creativity are inevitably more important than empathy and cooperation.	−1.36
6 Since STEM high schools mainly provide education on basic science programs, they do not adequately devote enough resources to education about business or innovation.	−1.80
3 STEM high schools are too focused on science education, so they have limitations in cultivating sociality through cooperation and joint research.	−1.90
2 Most research and education activities in STEM high schools neglect innovation through cooperation and sharing various ideas and resources.	−1.95
5 Since STEM high schools pursue dense competition among students, they do not provide an academic environment to solve problems through cooperation and collaboration.	−2.25

Note: Z-scores represent from strongly agree (+3), to neutral (0), and to strongly disagree (−3).

4.2. View 2: Open Innovation with Imagination from Arts

This view highlights the importance of this imagination-based open innovation. The details are shown in Table 5. It is necessary to operate open innovation programs through STEM cultural education or arts education programs. For example, like the Bronx High School in New York, it is necessary to stimulate imagination by providing education tailored to the fields of humanities and social sciences.

Table 5. View 2: Open innovation with imagination driving from arts and culture.

Q Statements	Z-score of Factor2
23 It is necessary to cultivate a mindset that promotes open innovation through cultural education or arts education programs.	2.11
22 STEM education in the open innovation education program must include the citizenship of making a better world.	1.84
15 Like the Bronx Science High School in New York, humanities and social literacy education should connect open innovation.	1.54
33 Students in STEM schools need to use open innovation programs in the community's daily problems around the school, rather than starting with overly broad goals or grand activities	1.49
32 From teachers and business managers, many argue that if an education program on OI works, students will learn more about the latest business ecosystem.	1.31
7 The government also needs to pay more attention to the introduction and expansion of open innovation education programs, design education programs for this, and allocate more budget.	1.17
19 STEM high schools need to provide students with knowledge of diversity through various language education and cultural education and systematically link this with open innovation education.	1.08
9 The curriculum of STEM high schools should encourage students to actively participate in business events or international conferences in the field of open innovation.	−1.24
10 STEM high school students should actively participate in various open innovation conferences and businesses to gain open innovation experience.	−1.26
2 Most research and education activities in STEM high schools neglect innovation through cooperation and sharing various ideas and resources.	−1.29
12 Due to the nature of STEM high schools that focus on gifted education, individual competencies such as individual creativity are inevitably more important than empathy and cooperation.	−1.51
30 It seems that most STEM high school students do not know anything about OI yet.	−1.47
4 It is not easy to find programs that systematically link business areas such as open innovation with science education in STEM high schools.	−1.70

Note: Z-scores represent from strongly agree (+3), to neutral (0), and to strongly disagree (−3).

4.3. View 3: Daily Life-Based Open Innovation Project

This view highlights that open innovation should involve everyday projects through the school curriculum and is shown in Table 6. It also emphasizes open innovation by finding a platform or smart solution that helps vulnerable groups such as the disabled and the elderly around the school with gaming programs and smartphone technology. For example, it would be useful for high school students if the open innovation experience started not too big initially but with the community's daily problems. However, this view

criticizes that STEM high school education does not accurately reflect the concept of open innovation (OI) to cultivate future entrepreneurship and venture leaders.

Table 6. View 3: Daily life-based open innovation practices.

Q Statements	Z-Score of Factor3
35 By promoting open innovation in the form of a project that embodies everyday life around the school, students should experience a sense of accomplishment, providing students with the driving force of open innovation.	1.94
33 Students in STEM schools need to use open innovation programs in the community's daily problems around the school, rather than starting with overly broad goals or grand activities.	1.87
34 It is necessary to approach open innovation step by step in an incremental way to find a smart solution or a platform that helps vulnerable groups such as the disabled or the elderly. We can use the skills and varying know-how (e.g., games, smartphone technology) from STEM students.	1.87
1 STEM high school curriculum and programs do not adequately reflect the concept of Open Innovation (OI) to cultivate future entrepreneurship and venture leaders.	1.22
8 The board of directors of the school or organizations in which parents participate should raise their interests and voices to actively introduce Open Innovation programs into the curriculum of STEM high schools.	1.09
31 STEM high school managers and teachers are still immersed in the traditional innovation concept and doubt the word "open innovation."	−1.02
17 Although STEM education seeks to provide education that makes students self-aware and learn, it needs to connect with open innovation properly.	−1.15
18 Although STEM high schools have no choice but to emphasize scientific logic and mind, it is necessary to learn the conflict management and negotiation skills inherent in open innovation in class.	−1.26
20 Even with an open innovation program in STEM schools, they should respect democratic civic education.	−1.39
23 It is necessary to cultivate a mindset that promotes open innovation through cultural education or arts education programs.	−1.39
22 STEM education in the open innovation education program must include the citizenship of making a better world.	−1.46
19 STEM high schools need to provide students with knowledge of diversity through various language education and cultural education and systematically link this with open innovation education.	−1.94

Note: Z-scores represent from strongly agree (+3), to neutral (0), and to strongly disagree (−3).

4.4. View 4: Critics of Conventional STEM Education

This view pays attention to the fact that current STEM high schools do not know much about OI and is shown in Table 7. This view criticizes that science high schools have limitations in cultivating sociality through cooperation and joint research, emphasizing only science education. Since science high school students are incredibly interested in going to college, there is a limit to gaining innovation experiences through joint research in the high school curriculum.

Table 7. View 4: Critics on current STEM education.

Q Statements	Z-Score of Factor4
14 STEM high school students are still very interested in going to top universities, so there is a structural constraint to paying proper attention to innovation through joint research in the high school curriculum.	1.87
30 It seems that most STEM high school students do not know anything about OI yet.	1.48
3 STEM high schools are too focused on science education, so they have limitations in cultivating sociality through cooperation and joint research.	1.42
13 The STEM high school curriculum should involve the value of joint research and cooperation.	1.36
35 By promoting open innovation in the form of a project that embodies everyday life around the school, students should experience a sense of accomplishment, providing students with the driving force of open innovation.	1.36
6 Since STEM high schools mainly provide education on basic science programs, they do not adequately devote enough resources to education about business or innovation.	1.28
20 Even with an open innovation program in STEM schools, they should respect democratic civic education.	1.24
29 STEM schools should run educational programs to fully experience open innovation examples of inside-out OI or outside-in OI.	−1.09
26 STEM schools' open innovation programs should focus on building communication skills.	−1.17
8 The board of directors of the school or organizations in which parents participate should raise their interests and voices to actively introduce programs in Open Innovation into the curriculum of STEM high schools.	−1.19
9 The curriculum of STEM high schools should encourage students to actively participate in business events or international conferences in the field of open innovation.	−1.19
10 STEM high school students should actively participate in various open innovation conferences and businesses to gain open innovation experience.	−1.24
31 STEM high school managers and teachers are still immersed in the traditional innovation concept and doubt the word "open innovation."	−1.28
25 STEM education needs to link current AI and data science knowledge with open innovation programs.	−1.78
27 STEM schools should properly incorporate megatrends in industrial ecosystems into their open innovation programs.	−2.03

Note: Z-scores represent from strongly agree (+3), to neutral (0), and to strongly disagree (−3).

4.5. View 5: Community Service-Driven Open Innovation with Communication

This view highlights the need for OI to start in the process of helping vulnerable groups in the community and is shown in Table 8 in detail. This view also emphasizes that science high schools' open innovation programs should focus on enhancing communication capabilities. For example, it is necessary to approach open innovation by finding a platform or smart solution that helps vulnerable groups such as the disabled or the elderly. Open innovation should promote daily projects around the school, and when completed, high school students should be able to feel the efficacy of OI performance.

Table 8. View 5: Community-based open innovation.

Q Statements	Z-Score of Factor5
35 By promoting open innovation in the form of a project that embodies everyday life around the school, students should experience a sense of accomplishment, providing students with the driving force of open innovation.	2.33
34 It is necessary to approach open innovation step by step in an incremental way to find a smart solution or a platform that helps vulnerable groups such as the disabled or the elderly. We can use the skills and varying know-how (e.g., games, smartphone technology) from STEM students.	1.99
26 STEM schools' open innovation programs should focus on building communication skills.	1.75
22 STEM education in the open innovation education program must include the citizenship of making a better world.	1.41
13 The STEM high school curriculum should involve the value of joint research and cooperation.	1.13
8 The board of directors of the school or organizations in which parents participate should raise their interests and voices to actively introduce Open Innovation programs into the curriculum of STEM high schools.	1.03
21 If open innovation education prevails in STEM high schools, it is first necessary to define why open innovation education is essential and for what.	−1.03
30 It seems that most STEM high school students do not know anything about OI yet.	−1.03
6 Since STEM high schools mainly provide education on basic science programs, they do not adequately devote enough resources to education about business or innovation.	−1.13
3 STEM high schools are too focused on science education, so they have limitations in cultivating sociality through cooperation and joint research.	−1.17
33 Students in STEM schools need to use open innovation programs in the community's daily problems around the school, rather than starting with overly broad goals or grand activities.	−1.31
31 STEM high school managers and teachers are still immersed in the traditional innovation concept and doubt the word "open innovation."	−1.37
32 From teachers and business managers, many argue that if an education program on OI works, students will learn more about the latest business ecosystem.	−1.75

Note: Z-scores represent from strongly agree (+3), to neutral (0), and to strongly disagree (−3).

4.6. Consensus Statement

Despite competing perspectives on open innovation across five factors, there is still a common ground that the five views support. The common view across the five perspectives is that the government needs to pay more attention to open innovation education programs and keep them. The diverse knowledge and patents available to private companies, research institutes, and governments do not automatically create new markets [10,36]. The link between innovative knowledge and ideas coming into the market is weak. The government should strengthen these links to create public policies that link various ideas and resources to market innovation and suggest policy tools to promote them.

4.7. Comparative Perspectives across Five Factors

Figures 1 and 2 show the spatial distribution of various perspectives centering on how well the five views understand OI, civic virtue, daily life-based OI, and STEM education. The specific differences and similarities that exist between these five perspectives are as follows.

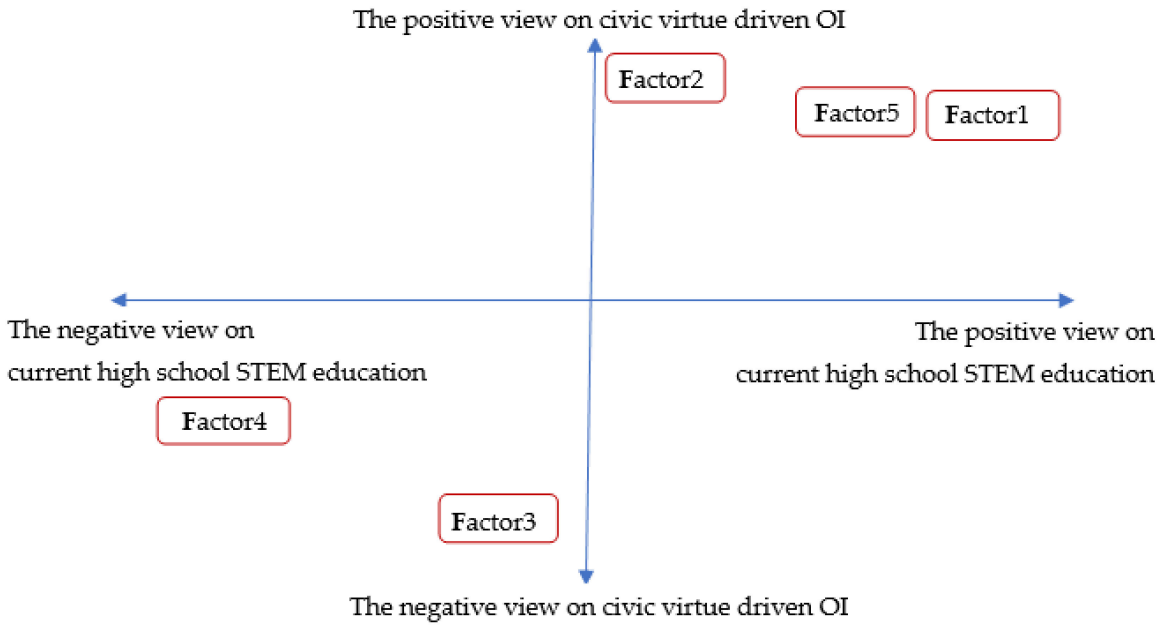

Figure 1. Competing views on STEM education and civic virtue across five factors.

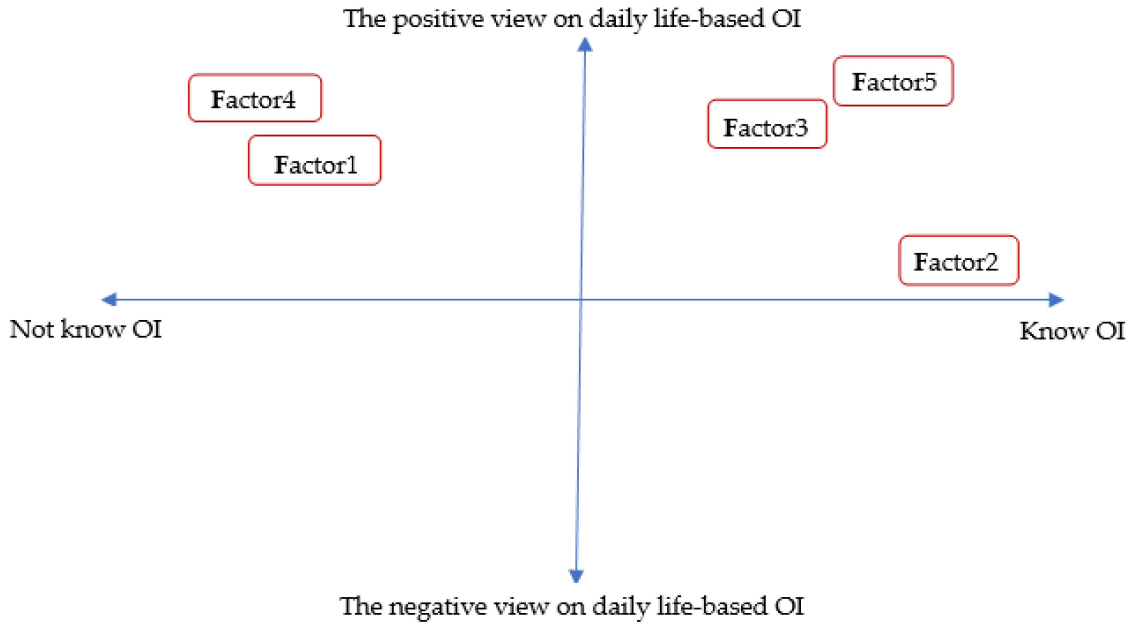

Figure 2. Competing views on OI knowledge and daily life-based OI practices across five factors. Note: These graphs are based on the Z-scores across five factors in Table 2.

Factor 1 (View1) and Factor 5 (View5) strongly support open innovation, which positively views STEM education and emphasizes civic virtue. Factor 2 (View2) is neutral about STEM education problems, but it strongly supports open innovation linked to civic virtue. On the other hand, Factor 4 (View4) points out the shortcomings of current high

school STEM education, and Factor 3 has a negative view on open innovation combined with civic virtue.

Factor 5 (View5) and Factor 3 (View3) are familiar with OI and emphasize daily life-based OI. Factor 4 (View4) and Factor 1 (View1) underline the need for daily life-based OI while criticizing current STEM education for not knowing enough about OI. Factor 2 (View2) also emphasizes daily life-based OI but is neutral to the criticism that high school STEM education currently does not know OI well.

Both Factor 5 (View5) and Factor 1 (View1) emphasize civic virtue-based OI and daily life-based OI education. However, Factor 1 (View1) points out the weakness that high school STEM education currently does not know much about OI.

5. Conclusions and Implications

This study explored various perspectives of high school STEM education from the OI perspective and how these perspectives can foster innovative leaders in the future. This study derives five views using Q methodology. These perspectives are (1) civic virtue-driven open innovation, (2) open innovation with imagination from arts and culture, (3) daily life-based open innovation project, (4) critics on conventional STEM education, and (5) community service-driven open innovation. Even though they have different and unique perspectives, there are still areas they all agree on. For instance, these five views concur with the Q statement that the government should support STEM education with more interest so that OI can be better integrated into STEM programs. In the future, along with government support for STEM education, STEM schools themselves need to introduce OI programs and help high school students to gain various OI-based experiences early, before entering university.

Innovation involves complicated value networks [37,38]. The creation and application of new knowledge do not automatically lead to innovation. Open science does not directly result in innovation [10]. Even if knowledge is opened and shared, new business models and products do not automatically generate innovation in the marketplace. The sharing of new and diverse knowledge creates a new market through collaboration and entrepreneurship [39,40]. Most recent innovation cases come from an open business model that connects the ideas, suppliers, and markets inherent in value networks. In this context, it seems crucial to provide more diverse innovative STEM education opportunities for developing social skills essential for fostering knowledge flows, new ideas, and peer learning. STEM education needs to incorporate these emerging innovation trends by including openness, networks, and cooperation in their curriculums. STEM education also needs to include the characteristics of social innovation as a driving force for curriculum innovation [41] A recent OECD report also suggested that collaboration in the STEM curriculum is essential to promoting education innovation [40]. The OECD report provided the five emerging educational models, including gaming, virtual laboratories, international collaborative projects, real-time evaluation, and skills-based assessment.

Our research of OI's different perspectives solely comes from STEM education programs for C Academy students and program managers. However, OI's various views found in the study can be used for deepening the understanding of the emerging desires of open, collaborative innovation for young students.

The limitations of this study involve several future research agendas. First, this study focused only on the viewpoints of stakeholders related to C Academy. The status assessment of STEM education in the study may not cover diverse situations in the U.S., which weakens the external validity of the findings. It is necessary to expand the research scope to all STEM programs in the United States and explore the various interactions and connections between STEM and OI to strengthen the external validity as well as the internal validity. Second, it is necessary to elaborate the theoretical framework and logic by developing more testable hypotheses in addition to the current exploratory hypotheses. Further research is needed to establish theoretical rationality for the five competing views. Third, the Q statements in this study presented the viewpoint that ICT technology or

platform-based OI education is necessary for STEM education, but it was not found to be significant. Further research needs to explore how ICT or platform-based OI programs link with STEM education with technological advances in the future.

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Appendix A. Q Statements about STEM Education and Open Innovation

Table A1. Questionnaire.

#	Q Statement
Q1	STEM high school curriculum and programs do not adequately reflect the concept of Open Innovation (OI) to cultivate future entrepreneurship and venture leaders.
Q2	Most research and education activities in STEM high schools neglect innovation through cooperation and sharing various ideas and resources.
Q3	STEM high schools are too focused on science education, so they have limitations in cultivating sociality through cooperation and joint research.
Q4	It is not easy to find programs that systematically link business areas such as open innovation with science education in STEM high schools.
Q5	Since STEM high schools pursue dense competition among students, they do not provide an academic environment to solve problems through cooperation and collaboration.
Q6	Since STEM high schools mainly provide education on basic science programs, they do not adequately devote enough resources to education about business or innovation.
Q7	The government also needs to pay more attention to introducing and expanding open innovation education programs, design education programs for this, and allocate more budget.
Q8	The board of directors of the school or organizations in which parents participate should raise their interests and voices to actively introduce Open Innovation programs into the curriculum of STEM high schools.
Q9	The STEM curriculum should encourage students to participate in business events or international conferences in open innovation.
Q10	STEM high school students should actively participate in various open innovation conferences and businesses to gain open innovation experience.
Q11	The STEM High School Education Mission needs to include open innovation concepts and values that emphasize joint research and collaboration.
Q12	Due to the nature of STEM high schools that focus on gifted education, individual competencies such as individual creativity are inevitably more important than empathy and cooperation.
Q13	The high school STEM education should incorporate the value of joint research and cooperation.
Q14	STEM high school students are still very interested in going to top universities, so there is a structural constraint to paying proper attention to innovation through joint research in the high school curriculum.

Table A1. *Cont.*

#	Q Statement
Q15	Like the Bronx Science High School in New York, humanities and social literacy education should connect open innovation.
Q16	Through various club activities such as orchestras, choirs, pop bands, and jazz bands, STEM high school students should build open literacy skills that help them in activities related to open innovation.
Q17	Although STEM education seeks to provide education that makes students self-aware and learn, it needs to connect with open innovation properly.
Q18	Although STEM high schools have no choice but to emphasize scientific logic and mind, it is necessary to learn the conflict management and negotiation skills inherent in open innovation in class.
Q19	STEM high schools need to provide students with knowledge of diversity through various language education and cultural education and systematically link this with open innovation education.
Q20	Even with an open innovation program in STEM schools, they should respect democratic civic education.
Q21	If open innovation education prevails in STEM high schools, it is first necessary to define why open innovation education is essential and for what.
Q22	STEM education in the open innovation education program must include the citizenship of making a better world.
Q23	It is necessary to cultivate a mindset that promotes open innovation through cultural education or arts education programs.
Q24	STEM schools should educate the recent economic ecosystem trends, such as platforms and sharing economy, with open innovation.
Q25	STEM education needs to link current AI and data science knowledge with open innovation programs.
Q26	STEM schools' open innovation programs should focus on building communication skills.
Q27	STEM schools should properly incorporate megatrends in industrial ecosystems into their open innovation programs.
Q28	Appropriate teacher recruitment and effective education programs are essential for establishing an open innovation program in STEM schools.
Q29	STEM schools should run educational programs to fully experience open innovation examples of inside-out OI or outside-in OI.
Q30	It seems that most STEM high school students do not know anything about OI yet.
Q31	STEM high school managers and teachers are still immersed in the traditional innovation concept and doubt the word "open innovation."
Q32	Many argue that if an OI education program works, students will learn more about the latest business ecosystem from teachers and business managers.
Q33	Students in STEM schools need to use open innovation programs in the community's daily problems around the school, rather than starting with overly broad goals or grand activities.
Q34	It is necessary to approach open innovation step by step in an incremental way to find a smart solution or a platform that helps vulnerable groups such as the disabled or the elderly. We can use the skills and varying know-how (e.g., games, smartphone technology) from STEM students.
Q35	By promoting open innovation in the form of a project that embodies everyday life around the school, students should experience a sense of accomplishment, providing students with the driving force of open innovation.

References

1. Madden, M.E.; Baxter, M.; Beauchamp, H.; Bouchard, K.; Habermas, D.; Huff, M.; Plague, G. Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Comput. Sci.* **2013**, *20*, 541–546. [CrossRef]
2. Taber, K.S.; Sumida, M.; McClure, L. (Eds.) *Teaching Gifted Learners in STEM Subjects: Developing Talent in Science, Technology, Engineering and Mathematics*; Taylor & Francis: Oxfordshire, UK, 2017.
3. Nene, S. The Value of STEM High School Intervention Programmes. Master's Thesis, University of Johannesburg, Johannesburg, South Africa, 2020.
4. Mihai-Yiannaki, S.; Varnava-Marouchou, D.; Konis, E.; Hadjichristodoulou, V. The success of STEM graduates in entrepreneurship training: A European case study. *Glob. Bus. Econ. Rev.* **2020**, *22*, 198–211. [CrossRef]
5. Bruce-Davis, M.N.; Gubbins, E.J.; Gilson, C.M.; Villanueva, M.; Foreman, J.L.; Rubenstein, L.D. STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *J. Adv. Acad.* **2014**, *25*, 272–306. [CrossRef]
6. Erdogan, N.; Stuessy, C.L. Modeling successful STEM high schools in the United States: An ecology framework. *Int. J. Educ. Math. Sci. Technol.* **2015**, *3*, 77–92. [CrossRef]
7. Tyszko, J.A.; Sheets, R.G. Illinois Innovation Talent Project: Implications for two-year institutions. *New Dir. Community Coll.* **2012**, *157*, 67–81. [CrossRef]
8. Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business Press: Brighton, MA, USA, 2003.
9. Chesbrough, H. Open innovation: Where we've been and where we're going. *Res. Technol. Manag.* **2012**, *55*, 20–27. [CrossRef]
10. Chesbrough, H. From Open Science to Open Innovation. 2015. Available online: https://www.fosteropenscience.eu/sites/default/files/pdf/1798.pdf (accessed on 3 February 2021).
11. Cricelli, L.; Greco, M.; Grimaldi, M. Assessing the open innovation trends through the Eurostat Community Innovation Survey. *Int. J. Innov. Manag.* **2016**, *20*, 1–30. [CrossRef]
12. Chesbrough, H. The future of open innovation: The future of open innovation is more extensive, more collaborative, and more engaged with a wider variety of participants. *Res. Technol. Manag.* **2017**, *60*, 35–38. [CrossRef]
13. Hossain, M.; Islam, K.Z. Ideation through online open innovation platform: Dell IdeaStorm. *J. Knowl. Econ.* **2015**, *6*, 611–624. [CrossRef]
14. Chesbrough, H. *Open Innovation Results: Going Beyond the Hype and Getting Down to Business*; Oxford University Press: Oxford, UK, 2019.
15. Bogers, M.; Zobel, A.K.; Afuah, A.; Almirall, E.; Brunswicker, S.; Dahlander, L.; Ter Wal, A.L. The open innovation research landscape: Established perspectives and emerging themes across different levels of analysis. *Ind. Innov.* **2017**, *24*, 8–40. [CrossRef]
16. Deming, D.J. The growing importance of social skills in the labor market. *Q. J. Econ.* **2017**, *132*, 1593–1640. [CrossRef]
17. Grönlund, J.; Sjödin, D.R.; Frishammar, J. Open innovation and the stage-gate process: A revised model for new product development. *Calif. Manag. Rev.* **2010**, *52*, 106–131. [CrossRef]
18. Nylén, D.; Holmström, J. Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation. *Bus. Horiz.* **2015**, *58*, 57–67. [CrossRef]
19. Ellison, S.; Allen, B. Disruptive innovation, labor markets, and Big Valley STEM School: Network analysis in STEM education. *Cult. Stud. Sci. Educ.* **2018**, *13*, 267–298. [CrossRef]
20. Fayolle, A. Personal views on the future of entrepreneurship education. *Entrep. Reg. Dev.* **2013**, *25*, 692–701. [CrossRef]
21. Henry, C.; Lewis, K. A review of entrepreneurship education research: Exploring the contribution of the *Education + Training* special issues. *Educ. Train.* **2018**, *60*, 263–286. [CrossRef]
22. Galloway, L.; Brown, W. Entrepreneurship education at university: A driver in the creation of high growth firms? *Educ. Train.* **2002**, *44*, 398–405. [CrossRef]
23. Franke, N.; Lüthje, C. Entrepreneurial intentions of business students: A benchmarking study. *Int. J. Innov. Technol. Manag.* **2004**, *1*, 269–288. [CrossRef]
24. Brown, T.E.; Ulijn, J. *Innovation, Entrepreneurship and Culture: The Interaction Between Technology, Progress and Economic Growth*; Edward Elgar Publishing: London, UK, 2004.
25. Beghetto, R.A.; Kaufman, J.C. *Nurturing Creativity in the Classroom: How to Discourage Creative Thinking in the Classroom*; Cambridge University Press: Cambridge, UK, 2010.
26. Wei, X.; Liu, X.; Sha, J. How does the entrepreneurship education influence the students' innovation? Testing on the multiple mediation model. *Front. Psychol.* **2019**, *10*, 1–10. [CrossRef]
27. >Ahmed, T.; Chandran, V.G.R.; Klobas, J.E.; Liñán, F.; Kokkalis, P. Entrepreneurship education programmes: How learning, inspiration and resources affect intentions for new venture creation in a developing economy. *Int. J. Manag. Educ.* **2020**, *18*, 1–13.
28. Hecker, S.; Haklay, M.; Bowser, A.; Makuch, Z.; Vogel, J. (Eds.) *Citizen Science: Innovation in Open Science, Society and Policy*; UCL Press: London, UK, 2018.
29. Schnugg, C.; Song, B. An organizational perspective on ArtScience collaboration: Opportunities and challenges of platforms to collaborate with artists. *J. Open Innov. Technol. Mark. Complex.* **2020**, *6*, 6. [CrossRef]

30. Kommonen, K.H.; Botero, A. Are the users driving, and how open is open? Experiences from Living Lab and user-driven innovation projects. *J. Community Inform.* **2013**, *9*. Available online: https://openjournals.uwaterloo.ca/index.php/JoCI/article/view/3156/4114 (accessed on 10 February 2021). [CrossRef]
31. Harhoff, D.; Lakhani, K.R. (Eds.) *Revolutionizing Innovation: Users, Communities, and Open Innovation*; MIT Press: Cambridge, MA, USA, 2016.
32. Gupta, A.; Dey, A.; Singh, G. Connecting corporations and communities: Towards a theory of social inclusive open innovation. *J. Open Innov. Technol. Mark. Complex.* **2017**, *3*, 1–34. [CrossRef]
33. Felin, T.; Zenger, T.R. Closed or open innovation? Problem solving and the governance choice. *Research Policy* **2014**, *43*, 914–925. [CrossRef]
34. Brown, S.R. A primer on Q methodology. *Operant. Subj.* **1993**, *16*, 91–138.
35. McKeown, B.; Thomas, D.B. *Q Methodology (Vol. 66)*; Sage Publications: Thousand Oaks, CA, USA, 2013.
36. Chesbrough, H.; Vanhaverbeke, W.; Bakici, T.; Lopez-Vega, H. Open Innovation and Public Policy in Europe. 2011. Available online: http://sciencebusiness.net/sites/default/files/archive/Assets/27d0282a-3275-4f02-8a3c-b93c2815208c.pdf (accessed on 10 February 2021).
37. Yun, J.J.; Won, D.; Park, K. Dynamics from open innovation to evolutionary change. *J. Open Innov. Technol. Mark. Complex.* **2016**, *2*, 1–22.
38. Yun, J.J.; Won, D.; Park, K. Entrepreneurial cyclical dynamics of open innovation. *J. Evol. Econ.* **2018**, *28*, 1151–1174. [CrossRef]
39. Kärkkäinen, K.; Vincent-Lancrin, S. Sparking Innovation in STEM Education with Technology and Collaboration: A Case Study of the HP Catalyst Initiative. 2013. Available online: https://www.oecd.org/education/ceri/OECD_EDU-WKP(2013)_%20Sparking%20Innovation%20in%20STEM%20education.pdf (accessed on 10 February 2021).
40. Bogers, M. Student-oriented teaching by using an open innovation game. In *Reflections on University Teaching*; Stenger, M., Rolfstam, M., Eds.; Syddansk Universitetsforlag: Odense, Denmark, 2011; pp. 10–22.
41. Schröder, A.; Krüger, D. Social innovation as a driver for new educational practices: Modernising, repairing and transforming the education system. *Sustainability* **2019**, *11*, 70. [CrossRef]