What Helped Me Innovate: Identified Motivation Factors from Canadian Innovators' Education Experiences

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Abstract

Past innovation research has focused on business contexts and prodigy, leaving the insights of today's successful innovators in a range of fields overlooked in their utility to inform the education of our next generation of innovators. This mixed method study combined surveys (n = 500) and interviews (n = 30) of Canadian innovators to identify motivation factors that could be leveraged in formal and informal education to make innovation more likely in Canada. The findings point to methods of maximizing expectancies and values, while proactively mitigating the costs of innovating.

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Recommendations are made for teachers, mentors, and decision makers for better stoking the capacity to innovate through education.

Keywords: innovation, innovators, maximizing innovative capacity

Résumé

Dans le passé, la recherche sur l'innovation s'est concentrée sur les contextes d'entreprises et les prodiges, laissant de côté les idées des innovateurs actuels qui réussissent dans un éventail de domaines dont l'utilité pour instruire de notre prochaine génération d'innovateurs a été négligée. Cette étude utilise une méthodologie mixte qui combine des sondages (n = 500) et des entrevues (n = 30) effectués auprès d'innovateurs canadiens afin d'identifier les facteurs de motivation pouvant être exploités dans l'éducation formelle et informelle pour rendre l'innovation plus probable au Canada. Les résultats indiquent des méthodes permettant de maximiser les résultats potentiels, tout en atténuant de manière proactive les coûts de l'innovation. Des recommandations sont faites aux enseignants, aux mentors et aux décideurs pour mieux alimenter la capacité d'innover par l'éducation.

Mots-clés : innovation, innovateurs, maximiser la capacité d'innovation

Introduction

The interest in capable thinkers who can devise, develop, and implement ideas makes innovators valued across disciplines and has transcended decades of scholarly efforts (e.g., Amabile, 1996; Fischer et al., 2019; Schumpeter, 1942; Soleas, 2018a). Since its inception in the 1940s, the study of innovation has tended to focus on innovation in business settings and institutions using the metrics of outcomes such as patents (Soleas, 2018b). It is important to distinguish between innovation and creativity. In this work, innovation, as elsewhere (Baregheh et al., 2009; Soleas, 2018b), is creativity with a sophisticated execution aspect that is not always present in creativity alone. Much more recently, innovation education has emerged as a discipline seeking to make innovation more likely (Gunnarsdottir, 2013; Shavinina, 2012). In fact, recognition of the importance of developing capacity to innovate is such that it is one of the new transferable skills on Ontario's redesigned student report cards (People for Education, 2017). When research has focused on the individual, innovation educators have tended to make excellent use of the lessons learned from prodigies and famous thinkers (e.g., Shavinina, 2013b; Yun Dai, 2013) as opposed to less known, more numerous innovators who lack the same name recognition whilst making their impact on humanity. In the shadow of this focus on prodigy, the insights of today's successful innovators are overlooked in their utility to inform the education of our next generation of innovators.

Examining the K–12 education experiences of today's innovators can shed light on the motivation factors, both promotive and hindering, that influence the development of young innovators. Understanding these factors can enable educators to leverage more of the innovation potential in today's students. The innovators of today have reported that they acquired their skills and built their capacity in both formal and informal educational environments (e.g., Koloniari et al., 2018; Liu & Chan, 2017). Although the motivational factors are the principal focus of this article, this study also explores these factors in the context of their differential occurrence in formal and informal settings as a useful means of exploring reported differences when they occurred. Whereas formal education has been defined by the UNESCO Institute for Statistics (2011) as primarily institutional, intentional, and planned thoroughly, informal education is characterized as taking place outside institutions and is therefore less structured and planned than formal education. Identifying and examining the motivation dynamics of both formal and informal education, as

identified by existing innovators in promoting their development, can help optimize both types in the conversion of innovation potential to innovation capacity.

Expectancy-Value Cost (EVC)

EVC (Barron & Hulleman, 2015; Flake et al., 2015) offers a unique, valuable, and novel holistic perspective on promoting innovation because it considers motivational factors that make innovation more likely to occur, as well as evaluating those factors that make it less likely to occur. EVC identifies that the motivation to complete tasks (including innovation) is influenced by expectancies of success (self-concept and self-efficacy) and the perceived values of the task (intrinsic, attainment, and utility value) (Barron & Hulleman, 2015). The motivation for complex tasks can be explained through the interaction of individuals' confidence in their ability to succeed in a given task (expectancies) and the enjoyment, importance, and usefulness they assign to the task (task values) (Wigfield et al., 2009). In other words, if learners expect to succeed and experience intrinsic or extrinsic values in innovating, they are more likely to try innovating of their own volition. Research that explores the various expectancies and values that motivate existing innovators has the potential to help educators understand how to motivate students to innovate and thereby enhance students' innovation potential.

Innovation, while often highly valued, also has contextual and psychological costs experienced by learners. Costs, in relation to motivation, go beyond the common conception of monetary price and include other detractive dimensions such as increased effort, time expenditure, and pressure, as well as the implications of failure (Flake et al., 2015). The costs of innovating as perceived by students may be higher than the expectancies and values, resulting in a deficit of motivation to innovate among our aspiring innovators. EVC simultaneously enables two approaches to innovation promotion in education: the identification of motivating factors in learning contexts enables easier promotion, while the identification of demotivating factors in learning environments provides targets for mitigating the costs of innovating. To make innovation more likely, educators must help students maximize the expectancies and values of innovating, as well as mitigate the costs. This research examined the educational experiences of innovators to identify the innovation expectancies and values that education can build, and the costs of innovating that education can mitigate. The findings can be leveraged to inform the innovation

education of learners so that they can realize their personal potential to innovate in their work and lives.

Research Questions

This study used EVC to investigate the educational experiences of innovators as guided by the following questions:

1. How do Canadian innovators believe education can help students balance the expectancies, values, and costs of innovating? (Mixed)
    a. What educational experiences and factors do Canadian innovators consider important in the promotion of innovation? (Qualitative)
    b. Were informal or formal educational experiences seen as more positively impactful in helping aspiring innovators? (Quantitative)

Methodology

This study adopted a two-phase, primarily qualitative design combining semi-structured interviews and a survey of Canadian innovators. Interviews were conducted with a diverse, multidisciplinary sample of Canadian innovators (referred to here as "interviewees"; $n = 30$), which informed the development of the survey administered to a larger sample of Canadian innovators ("survey respondents"; $n = 500$) (Soleas, 2020). This study received ethical clearance from the Queen's University General Research Ethics Board and was conducted in strict compliance with the ethical principles of Canada's Tri-Council Research Agency.

Questions about participants' employment, current innovation endeavours, and past achievements guided decisions about their eligibility to participate in the study. Kaufman and Beghetto's (2009) model of creativity, which encompasses four levels of proficiency on a continuum ranging from mini- to big-C creativity, guided design of a framework to establish each participant's level of innovation proficiency. In this study, the continuum was applied to innovation as follows: Mini-I innovation constitutes innovative student behaviour (e.g., in-class problem solving); Little-I is local or common innovative behaviour (e.g., inventing a new baking recipe); Pro-I includes professionals

who innovate for a living (e.g., surgeons refining an existing technique); and Big-I innovation corresponds to those who have made renowned innovative contributions (e.g., inventing a new renewable energy source). Participants who did not demonstrate at least Mini-I innovation (innovative student behaviour) were deemed ineligible for inclusion in the interview study sample and were thanked for their interest.

Interviews

Interviewees included aspiring or recognized Canadian innovators (aged 21–87) as determined by the researchers and a trained research assistant on a consensus model. Interviewees were selected based on innovation award winners and nominations by peers; those with newsworthy achievements clearly of an innovative nature were also selected. The interviewees represented a variety of innovator level groups, including Little-I (n = 10), Pro-I (n = 15), and Big-I innovators (n = 5). Invitations yielded six innovators from five disciplines—(1) science, technology, engineering, and mathematics; (2) social services; (3) education and academia; (4) arts; and (5) business—for a total of 30 interviews ranging from 45 to 96 minutes (see Table 2). Seventeen innovators identified as being men, while 11 identified as being women; two innovators did not identify within the gender binary. During the interviews, innovators were asked to answer eight open-ended questions about their motivations toward, experiences with, and conceptualizations about innovation, followed by supplementary queries to capture latent details as well as demographic factors that guided analysis. Interviews were transcribed verbatim and thematically coded by the researchers (Basit, 2010; Braun & Clarke, 2006) using ATLAS.ti v8.3.16 qualitative analysis software. Open codes were clustered into subthemes, and then organized into groups of expectancies, values, and costs with research assistants providing the ability to establish inter-coder reliability and consensus about the themes in all cases.

Survey Responses

Survey respondents were invited to participate by email and social media. Respondents completed the 15-minute questionnaire composed of open responses (barriers, supports, and experiences) and closed-ended items (demographics and EVC Likert-like scales; not used in this study.) Responses were verified for eligibility for study inclusion through

a combination of reported location, first three digits of IP address, occupation, and role description and then sorted into disciplinary foci (sciences, technology, engineering, and mathematics = 107; social services = 105; education and academia = 94; arts = 76; and business = 118) and innovator level groups (Mini-I = 31; Little-I = 241; Pro-I = 180; Big-I = 48). In terms of gender, 243 respondents identified as male, 210 identified as female, 3 identified as non-gender binary, and 44 preferred not to disclose their gender. Like the interviewees, survey respondents (n = 500) were also an interdisciplinary, multicultural sample of Canadian innovators (aged 20–91). Closed-ended items were data cleaned and analyzed in SPSS v24. Open-ended items were coded thematically in ATLAS.ti v8.3.16 and in alignment with the analysis of the interview responses.

Results

Innovators described their experiences and made recommendations based on these experiences. These responses were thematically analyzed and then categorized into the EVC theoretical framework. The results are primarily qualitative in methodology. The closed-ended items of the surveys were primarily used to answer whether informal or formal educational environments were more frequently reported to be more promotive of innovation. All survey closed-ended items were found to have Cronbach's alpha values in the range of very good to excellent (α = 0.81–0.90).

Educational Factors that Build Expectancies

Education can build expectancies as a means of supporting innovation education. Innovators in the surveys and interviews described six ways that education could have contributed to their innovative work, including: building a culture of innovation, providing stable access to opportunities, stimulating thinking through offbeat activities, fostering meaningful mentorship and peer relations, modelling innovation, and directly teaching innovation-relevant knowledge and skills.

A culture of innovation. Surveyed and interviewed innovators explained that some contexts had supportive cultures that made people feel more comfortable, confident, and capable when innovating. Within the more formal education settings, innovators

praised classrooms where an innovation culture encouraged learners to experiment. In more informal settings, they praised co-curricular learning environments, crediting examples like debate club and robotics for exposing them to new ideas. Interviewee 25 described the importance of "creating a culture where people are free to think differently, they're not punished, they're not demeaned." Indeed, the aegis of safe spaces in an innovation culture was described consistently by interviewees as crucial to their confidence in taking chances and thus building their capacity. Interviewee 28 described a tangible example of an innovation culture in a past institution where "everywhere there were posters that said 'We ask why not?' It was part of the culture that that's what everybody started doing all the time." Innovators depended on these early safe spaces and innovation-friendly cultures to develop into the resilient thinkers who would later innovate in their areas of endeavour. In order to build expectancies in an education context, participants indicated the benefits of developing an innovation culture that encourages aspirants to try new things and community initiatives that establish innovation as a norm.

Stable access to resources, spaces, and opportunities. In both formal and informal educational settings, innovators extolled well-equipped, self-directed exploration of the world's knowledge, which helped them make a habit of exploring and pushing boundaries of contemporary thinking. In more formal settings, they credited teachers who encouraged and provided access to opportunities to further learning, like bringing in guest speakers, internet exploration assignments, and other means to explore ideas in an engaging and collaborative manner. Innovators identified the value of informal education environments, such as science clubs and improvisation groups, as providing stimulating learning environments and ideas. Interviewees recalled that these environments helped them develop their innovation potential. Interviewee 1 explained, "You've got to have places where people can talk, where they can work, there's tools that they can use to prototype." This thread was found elsewhere as several innovators (for example, Interviewees 2, 5, 6, 17, 24, and 30) commented on the need for hubs for prototyping. It was innovators' consistent access to these opportunities, resources, and spaces that helped them build their innovation expectancies, and which they in turn recommend for the support of future innovators.

Offbeat activities. Surveyed and interviewed innovators credited offbeat learning activities, including robotics competitions, science fairs, and school musicals, with building their confidence to innovate. In more formal education settings, innovators fondly recalled classes that went "outside the box" by, for example, adopting flipped classrooms, makerspaces, and studio models with long blocks of time to make learning more authentic and immersive. They also credited offbeat tasks like designing zoos for biology, planning cities, and other open-ended assignments that really made students think. These offbeat or informal activities and contexts fuelled innovation by breaking routine and creating opportunities beyond the norm of conventional classrooms. Extolling the virtue of more informal and offbeat learning spaces, Interviewee 2 described his work travelling to schools with a mobile makerspace: "We wanted the trailer because we didn't want the feel of their regular classroom," and further elaborated that, "in their own schools, they already have a dynamic set up in their classroom." Innovators across disciplines credited informal learning opportunities, especially those that facilitated offbeat approaches to learning, even within formal education, as building their innovation expectancies.

Mentorship and peers. Innovators retrospectively credited the mentors and peers they connected with through formal education as being crucial supports in their early innovating endeavours. They frequently explained that structured collaboration in their schooling helped them grow accustomed to working with their peers on projects and accomplishing goals, crediting this collaboration with building their later capacity to innovate. Collaborating with peers was held in high regard by interviewees, as exemplified by Interviewee 24: "I think working with other people is valuable for innovating because it involves analyzing ideas because now, you're in a situation where the ideas aren't just coming from you." In informal settings, innovators found that mentoring in libraries, clubs, and extracurricular activities aided them with finding new perspectives and building a network of colleagues that they credited with building their later capacity to innovate. Interviewee 23 credited mentors for her innovating and likened innovation "to jumping off a cliff with the parts and assembling it on the way down. If you don't have people that can help guide you on that way down, it is less likely to end well." Interviewees elaborated that mentors often articulated belief in their potential and would encourage them to follow through on their ideas. Innovators of all disciplines credited peers and

mentors with building their expectancies in learning contexts as nurturing their capacity to innovate through building their capacity for teamwork and providing informed support.

Modelling innovation. Innovators described innovating as initially seeming like an ambitious or impossible goal to them during their schooling, but teachers and speakers modelling innovating helped to humanize the process and make it seem reachable. Without an example, even one outside their area of interest, innovators were uncertain if they would have done the innovating that they did. Interviewee 16 explained that "I think it's especially helpful to hear about the struggle and the hard stuff that they've gone through. They don't seem superhuman." From the responses of innovators, modelling innovation in schools can show students not only how to innovate, but that innovation is something within their capability—something that real people like their teachers and they themselves can achieve, thus building their expectancies.

Direct teaching of innovation knowledge and skills. Innovators in both the survey and interviews credited formal education with contributing to their expectancies and perceived capacity to innovate as a source of necessary content foundation, process skill development, ideas and design training, and developing systems and critical thinking.

Content-specific skills. Interviewees found strategy, writing, leadership, cost accounting, communication, and specific disciplinary content knowledge especially pertinent for them to learn to innovate successfully (e.g., dance techniques for a dancer, or basic mechanics for a bicycle builder). Such content knowledge was reported by the surveyed innovators as contextual, differing from one field of endeavour to the next, and tended to be seen as a gatekeeper that made innovation possible. Interviewee 12 offered the example, "If you can't communicate your ideas, you can't write your ideas. You need writing skills; you need to be able to write proposals." To innovators, a brilliant intellect without necessary knowledge and skills would be insufficient to drive innovation. The content-specific knowledge and skills built by formal education were seen as crucial to their innovation confidence and were characterized as foundational for the expectancies that would support the rest of their careers.

Creative and problem-solving process skill development. Both innovator samples credited the educational opportunities that they had to learn about innovation

processes, including creative and problem-solving processes, as building their future capacity by giving them a framework they could transfer across contexts. Interviewee 20 advocated for more teaching time devoted to the process of innovation and remarked, "I'd say that's the biggest barrier—a focus on products as opposed to processes." Schools, it was argued, can "provide something maybe even more important than the content. [They] provide the students an understanding of the process of how to succeed in a messy world" (Interviewee 7). The content was deemed important to innovation confidence, but survey respondents and interviewees also emphasized the need for schools to develop distinct student creative and problem-solving processes as a means of developing expectancies.

Idea and design development training. Both samples of innovators discussed the importance of education, schools in particular, for teaching design thinking as well as tools and processes for idea development. Interviewees credited their education with providing them with techniques that enabled them to cultivate their ideas, including "structured brainstorming" (Interviewees 1, 6, 17, 21), "problem setting" (Interviewees 1, 6, 9, 13, 16, 22), and "design thinking" (Interviewees 1, 5, 6, 8, 21, 25, 28, 30). Interviewee 16 described, for example, "a place called the problem lab where they don't focus on solutions at all. They just focus on deeply understanding problems. It's much better to start with the problem and then try to figure out the solution." These and other techniques were emphasized as skills and techniques innovators could learn in schools to increase their expectancies and capacity.

Systems and critical thinking. Innovators in the survey and interview samples also identified formal education as a site for developing their systems and critical thinking. Participants credited systems thinking with enabling learners to isolate and critically examine the mechanics of a part of a system. As explained by Interviewee 9, education interested in stoking innovation needs to "develop systems thinking, and work to ingrain critical thinking into the way that people approach every instance of their lives." Interviewee 6 commented on the importance of "any class that paired critical thinking with the real world" when it comes to fostering innovation. Innovators identified that schools could nurture systems and critical thinking as an important expectancy aspect of preparing students to innovate.

Expectancy-related educational factors were found to occur in both formal and informal contexts. Content-specific skill and knowledge acquisition were acquired more frequently in formal settings. Mentorship, on the other hand, was found to more commonly occur in informal settings. The expectancy-building properties of modelling innovation, an innovation culture, and stable access to opportunities were found in both informal and formal learning contexts.

Educational Factors that Build Task Values

Much like expectancies, education can also build task values as a means of supporting innovation education. Innovators in the surveys and interviews described two groupings of positive effects that educational environments could have: boosting attainment task-value and fostering innovation's intrinsic task-value for learners.

Attainment value: Promoting autonomy and taking the lead. Educators can make learners' innovation efforts more fulfilling by providing students the freedom and means to autonomously pursue their ideas. Surveyed innovators explicitly credited the teachers who provided them with the freedom to experiment with new ideas in formal education. They also extolled the virtues of empowering learners to pursue their ideas and learn how to make important decisions for themselves in informal learning contexts. Interviewee 29 explained that "a learning environment where you can empower the learners to grab hold of their own destiny and give them some open-ended questions that they really care about" would recruit more interest. Innovators explained that informal opportunities for independent reading and work, as well as opportunities to learn by doing, made innovating seem more valuable as a source of freedom in the otherwise very structured process of schooling. Explaining how teachers could promote autonomy, Interviewee 18 suggested that teachers could tell students, "You're going to find a way to innovate and you're going to come to me and tell me what your barriers are and I'm going to help you overcome those barriers." Promoting autonomy was portrayed as a tool for building attainment value, and thus recruiting engagement in early innovating, but also developing independent thinking skills that would later support innovating endeavours.

Attainment value: Connecting to real world outcomes. Innovators attributed their opportunities in school to wrestle with real-world issues as building up the perceived

importance of future innovating. Surveyed innovators offered examples of activities schools could provide—including volunteering, final projects with real-world relevance, and interactions with bonafide innovators who clearly articulate the importance of innovating—as having strong potential for building the perceived value of innovating. Interviewees also described the importance of perceived connectivity to the wider world. Interviewee 22 advocated for "giving them some real-world outcomes. Anything that connects to the real world is immediately going to spark a different kind of engagement." Interviewee 29 gave another example: tasking students with "using Twitter to engage with real world publics on real time conversations on very relevant issues." She elaborated that "you see students going, 'Oh, this really matters! I'm not just writing this for my professor.'" Schooling can boost the perceived importance, an attainment value, of innovating by making very clear the connection and impact innovating has on students' lives and wider society.

Intrinsic value: Novelty in learning spaces. Innovators described the importance of novelty, or shaking things up, as a way of getting students engaged in innovating in their schooling as well as making the experience enjoyable. Surveyed innovators linked open-ended projects and the enjoyment of novel activities in class with the beginnings of recognizing intrinsic value in innovating. As described by innovators, teachers who made their activities engaging tended to focus on opportunities that helped students apply their skills. Interviewee 6 described an example of an enjoyable activity that taught him necessary content. His teacher designed a simulated scenario where he "participated in a model United Nations and had to negotiate" trade deals with his peers. He found it enjoyable because he was building the skills he would later use as a Canadian trade envoy. Innovators tended to describe the emphasis on novelty as a way of capturing and retaining student interest and viewed these novel shakeups as outlets for expression that serve as a catalyst for later interest in innovative endeavours.

Intrinsic value: Responding to student interests. Innovators credited interest-responsive teaching with stoking their later innovative behaviour. Surveyed innovators praised teachers who inspired them to try new things and encouraged students to channel their passions into their assignments and learning. Interviewees commonly described the impact that teachers could have when they invited students' own interests into the

curriculum. Interviewee 24 reported that "The teachers I would vividly remember as being instrumental in me doing anything productive with my life have just been the ones who respond to what my interests are." In another instance, Interviewee 10 explained that one teacher among many told her to persist in her then-unorthodox style of art, stating, "He told me 'You should keep it up.' I still think about that to this day. I'll send him one of my installations." Teachers who encouraged students to pursue their own interests helped make school and the process of innovating more intrinsically valuable.

Intrinsic value: Nurturing curiosity. Innovators reported the importance of education nurturing curiosity as stoking an intrinsic value. Surveyed innovators described curiosity-supportive environments in schools as ones that required students to try new ideas, held an expectation of creative and analytical outputs in assignments, and ensured that opportunities to apply advanced skills were available within a structured environment. Interviewee 15 expanded on the above requirements by saying, "I would say develop the curiosity, provide some foundation, nurture it, and one of the best ways to nurture it is to provide opportunities to do it." Surveyed and interviewed innovators cautioned that, unfortunately, formal schooling often punishes creative curiosity as non-conformity. Interviewee 29 explained, "Humans are by nature curious beings and that we do sometimes have the curiosity beaten out of us… If you want people to really truly foster and develop curiosity, then you have to be deliberate and purposeful about that." Analysis of the responses of innovators showed that without nurturing the curiosity of students, innovation's intrinsic value would seldom be developed by formal education.

Value-building factors were reported more frequently in formal education settings and included promoting autonomy, real-world applicability, novel approaches, responding to student interests, and nurturing curiosity. The general trend within the reported examples was that the value-building factors were more noticeable in formal education settings because they tended to occur less frequently. Given that formal educational contexts were often compulsory and informal educational contexts were often attended by choice, it is indicative of the value that innovators ascribed to their informal education experiences such that they continued to attend them. The same value-building factors may well have been present in participants' informal learning but were not highlighted by participants, perhaps because they were part of an expected norm.

Educational Factors that Mitigate Costs

Innovators isolated specific educational methods of mitigating the costs of innovating in the classroom, including a focus on developing processes and debriefing failure. It is notable that surveyed and interviewed innovators did not frequently report costs associated with informal education.

Focus on developing the process and skills instead of immediate outcomes. Innovators credited cost-mitigating efforts made by teachers in the process of stoking their innovation as crucial to their continued engagement in innovating. Surveyed innovators described cost-mitigating efforts as formal educators choosing not to stifle innovation with an overemphasis on compliance and outcomes. Interviewees tended to advocate for not directly evaluating creativity at all. Rather, they focused on developing the process instead of the immediate outcome. Interviewee 20 advocated for "learning activities that provide opportunities for self-expression without evaluation attached." She suggested providing "lots of opportunities to be creative without grades attached." Interviewees emphasized the need for managing the perceived risk that students would feel when learning innovation skills. Interviewee 24 offered the idea of "not measuring success by the outcome but measuring success by the process and growth" as a strategy for managing this risk. Formal education systems can manage the costs of learning to innovate by focusing on developing the process rather than evaluating outcomes, thereby making learning to innovate less risky.

Debriefing failure. Innovators credited being taught how to confront failure in their formal and informal education as a key to their resilience against the inevitable setbacks innovating entails. Surveyed innovators described powerful learning experiences moderated by teachers and mentors who helped them accept and learn from failures. Interviewees also noted the importance of resilience-building experiences, such as "getting comfortable learning about what didn't work and how to come back at it with future iterations" (Interviewee 7). According to innovator responses and exemplified by Interviewee 19, this would look like "the chance for the students to fail in this task, and to have them realize that this is not failure but a natural part of the process." Interviewee 20 explained that educators need to prioritize helping students to "deal with failure emotionally." The responses point to a need for informal and formal education to not shy away from having

students experience failure, but rather to focus on ensuring that it is a constructive learning opportunity that will enable them to be resilient when failure occurs. The vast majority of cost-mitigating educational factors were reported in formal educational settings. Given that formal education features evaluation more prominently and with longer-term implications (e.g., grades), innovators' experiences concentrated on formal schooling as the site where focusing on developing processes and debriefing failure were most necessary for mitigating the costs of innovative behaviour.

Comparing Formal and Informal Education

When asked about the effects of formal and informal education, participants tended to view environments guided by curriculum (including classrooms, post-secondary programs, enrolled scholarly courses, and sessions with a regionally mandated curriculum) as formal. Other types of typically less-structured environments like clubs, mentoring, collaborative networks, and learning on the job were thought of as informal education. Surveyed innovators were less positive about formal education than informal education in terms of which had a positive effect on their innovation development. Analyzed responses from the survey revealed that innovators tended to rate informal (m = 5.98, SD = 1.12) over formal educational experiences (m = 5.22, SD = 1.32) as positively impactful to their development as innovators, constituting a significant difference with a significant effect size (p = <0.001, df = 499, d = 0.62). Male innovators (m = 5.58, SD = 1.03) tended to find formal schooling more useful than their female peers (m = 5.02, SD = 1.11) resulting in a significant difference and a medium effect size (p = <0.006, df = 499, d = 0.52). Formal education was described as having a positive impact on the development of innovators, but not as strongly positive as informal education.

Formal education has merits and builds the foundation. Innovators indicated that formal education has a role in stoking innovation, particularly in building confidence, teaching innovation processes, and the transmission of key disciplinary knowledge that serves as a foundation for innovating. Ninety percent of interviewees and 54% of surveyed innovators echoed these sentiments in their responses, as exemplified by Interviewee 27: "Like Picasso ventures into abstraction, but he's classically trained. He needed to know shape and form and be able to do all the nuts and bolts before the innovation can

[could] happen instead of just starting off the bat." In this way, innovators described formal education as laying the foundational skills, perspectives, and capacities that make the breakthroughs in informal education possible. As Interviewee 26 explained, "informal environments augment the formal educational experience and can get students involved in problem-solving in a more realistic setting more closely mirroring the rest of their lives."

Informal education provides rich opportunities. Innovators credited informal education as being the primary source of opportunities to engage deeply with innovation. Surveyed innovators frequently criticized formal schooling as actively stifling innovation, citing the need for compliance to avoid punishment, except on the rare occasion where an inspirational teacher was involved. Interviewee 3, for example, when asked where one learns to innovate, responded, "pretty much anywhere but a classroom." Informal education, by comparison, was unanimously portrayed as a source of opportunities to develop innovation, with students tending to participate by choice and where they were not punished for exploring their ideas. Some of these opportunities were voluntary, such as enrolling in music lessons or going to space camp, while others were necessary reactions to their environments, such as needing to become more time-efficient in order to have time to do their chores and still spend time with their friends.

Discussion

This study asked innovators to describe the educational factors that enabled them to develop into innovators. Their responses were considered and analyzed through the lens of Expectancy-Value-Cost theory and, when applicable, differentiated by their presence in formal or informal settings.

Expectancies

Educational factors associated with expectancies were the strongest and most frequently described in terms of what education could do to support young innovators, according to both samples of innovators. Innovators tended to credit their innovating expectancies or confidence to endeavouring in an innovation culture that encouraged experimentation, as previously hypothesized by Bhaduri and Kumar (2011). Study results indicated that

the learning activities most credited by innovators for building expectancies were noticeably "offbeat," including robotics competitions, school musicals, and makerspaces. The effectiveness of such "offbeat" learning environments is a key consideration in emerging literature investigating their promise (e.g., Jonsdottir & Macdonald, 2013; Kirsten & Du Preez, 2010; Maravilhas & Martins, 2019).

Innovators in both samples, and consistently across disciplines and formal and informal education settings, leaned heavily into the aegis of safe spaces as key to building innovation expectancies. Study participants described being motivated to innovate when risks were minimized, as has also been found in other studies in the recent literature (Chaiechi, 2014; Hendy & Barlow, 2012; Soleas, 2018a). A safe environment was key, but stable access to opportunities and resources was also credited in both formal and informal education settings as significant for building expectancies and therefore supporting innovation. This resource access view was in contrast to some previous studies that have identified the efficacy of sudden surges in resources (Carè et al., 2018; Chaiechi, 2014). Innovators in this study credited stability and consistency with making them more confident, and therefore more likely to innovate as a result of the knowledge that they were safe to make mistakes. This security gave them the confidence to push boundaries, which facilitated discovery and their future ability to find new solutions.

By far the strongest consensus among innovators was that their expectancies, specifically innovating confidence, was increased due to the support that they experienced from mentors and peers, which complements the findings of recent innovation literature contributions that found that support from mentors and peers promotes innovation (e.g., Aarikka-Stenroos et al., 2017; Oyemomi et al., 2019; Pihlajamaa, 2017). Broadly speaking, mentors tended to make their mark in informal circumstances, whereas the most impactful peers tended to act in formal education, a distinction that is thus far not articulated in the innovation promotion literature. As an extension of mentorship, innovation development was facilitated by modelling innovative behaviour, which built expectancies. The finding that participants appreciated innovation being modelled hints at the importance of an active approach to innovation education featuring, for example, the showcasing of intelligent risk-taking (e.g., Kinney et al., 2015), and demonstrating the virtues of following a process when innovating (e.g., Krathwohl, 2002; Li et al., 2013; van Grinsven & Tillema, 2006).

Direct teaching of innovation-relevant knowledge and skills in formal education, as credited for building expectancies by the innovators in this study, represents a relatively unique finding given the focus in innovation education on activating previous knowledge and developing prodigies (e.g., Shavinina, 2012; Yun Dai, 2013). Innovators placed an emphasis on the value of being taught different strands of innovation-relevant thinking—strands more commonly associated with disciplinary learning, including systems thinking (e.g., Lee & Sohn, 2019), critical thinking (Olivares et al., 2013), creative processes (e.g., Fischer et al., 2019), and design thinking (e.g., Norman & Verganti, 2014). Innovators prioritized the learning of these various types of thinking in formal education, with a particular emphasis on acquiring these skills in school as a means of building their innovation expectancies.

Values

While expectancies were especially impactful according to innovators, the ability of education to foster attainment and intrinsic values for innovating in learners was also well-articulated. Attainment values were found to be built in education via providing opportunities to pursue goals autonomously and reinforcing the connections between learning and the real world. Providing autonomy to pursue ideas was a key method that education, especially through schooling, utilized to build attainment value. This aligns well with previous findings in the literature, especially social innovation studies (e.g., Radicic et al., 2016; Thorpe & Figge, 2018), that attainment was a key consideration that was acquired from the experiences that learners had prior to their gainful employment. Although not specifically identified in innovation promotion literature, other studies have highlighted that activities that are more closely connected with the world outside of schooling add to the perceived importance of the underlying content (Costa et al., 2015; Kandiko, 2013; Kruglanski et al., 1971; Sorice & Donlan, 2015).

Intrinsic task values for innovating were found to be built through providing engaging and novel experiences in learning spaces, responding to student interests, and nurturing curiosity. Despite a lack of research about novelty in innovation education, there is widespread recognition that innovators enjoy activities that push boundaries as they capture and maintain their interest (Kirsten & Du Preez, 2010; Tan, 2007), all the while building the task values that will drive their future innovating. Innovators credited

teachers who responded to their interests as helping them appreciate the value of innovating, paralleling the findings of research on the efficacy of leaders who consider the interest of their workers (e.g., Bolderdijk et al., 2018; Sergeeva & Zanello, 2018; Yidong & Xinxin, 2013). Innovators identified that having their curiosity nurtured built intrinsic task value, as did the careful curation of activities that required them to think differently but within their field of interests (e.g., Cordero et al., 2005; Fischer et al., 2019; Minarcine & Shaw, 2016). It is worth noting that utility values (analogous to external extrinsic rewards) were not found to be relevant to innovation development in education, as demonstrated by their complete absence from innovator responses and respondents' aversion to having early innovative works graded.

Costs

While participants rarely described experiencing, nor recommended, cost mitigation in informal education contexts, formal education was identified as having specific opportunities to help students mitigate the costs of innovating. Innovators urged schooling to focus on student skill development and refining processes, rather than compliance and outcome metrics, which were reported to exacerbate the costs of innovating. This stands in contrast to the findings in innovation literature, which have focused on outcome metrics as the principal outputs of innovation promotion (Smith & Sandberg, 2018; Wendelken et al., 2014). A significantly smaller segment of innovation promotion literature has focused on developing the skills underpinning the innovation process and an increased capacity to innovate as the primary outputs of innovation promotion (Everard & Longhurst, 2018; Montani et al., 2014; Soleas, 2018a), which would align well with educational programs. Additionally, innovators positioned schooling as having an opportunity to develop students' ability to confront failure as a way of mitigating costs. This finding adds to our understanding of innovation education, which has focused to this point on the importance of adding skills and creating a supportive environment in schools to build capacity (Noonan, 2013; Shavinina, 2013a). Conceptualizing failure and debriefing it as an opportunity is in alignment with literature in educational science (Elliot & Dweck, 2013; O'Rourke et al., 2014), and represents a promising new direction for innovation education.

Informal Versus Formal Education

Informal education has not been thoroughly studied in the context of innovation education, which has instead focused on formal education, including classrooms and schools (e.g., Makri et al., 2009; Nold, 2017) and structured programs (Sandberg, 2013). The findings of this study point to informal education being at least as impactful for innovators' development as formal education. Among expectancies and costs, formal and informal education were found to have different roles. Formal education was found to primarily build skills and knowledge and to be the site where cost-mitigating was most necessary, whereas informal education was reported to be an effective outlet and safe space for the application of the knowledge and skills. The dearth of research elsewhere, combined with the promise of informal education settings as identified by innovators in this study, indicates the need for further study of informal education and its potential contributions to innovation education, especially as a principal method for exploring young innovators' individual interests. This study points to the role of both informal and formal education in building the expectancies and values of innovating, whilst mitigating its costs, thereby motivating young innovators and supporting their development.

Implications

This study has implications for professional practice for teachers, innovators themselves, and for future research in innovation education and promotion. For teachers, this study suggests that learning in classrooms can benefit from activities that push the boundaries of a traditional classroom, particularly hands-on activities and activities where students need to begin with an initial idea and progress to a tangible, ideally real-world application. Additionally, this study suggests future innovators need their teachers to carefully curate the activities that are done in class, ensuring that they nurture and indulge student curiosity, in particular allowing them to pursue their "burning" questions whenever possible.

A signature finding of this study is the complete lack of innovator recognition of the role of utility value, analogous to external extrinsic rewards, in broader motivation study (Flake et al., 2015). Innovators described the grading of evaluation of the outcomes of creativity, or compliance with overly structured expectations, as actively hindering future willingness to innovate, making the evaluation of innovation outcomes or punishing

intelligent deviations from norms in learning environments counter-productive. This study supports the notion that extrinsic rewards, such as grades, could be overemphasized in their efficacy and application. This study also provides insights into how innovators can better sustain their own motivation to innovate, by seeking informal learning environments where they can practise their skills in a safe environment with adequate peer support. Additionally, innovators can retain their motivation by self-advocating to be allowed to choose interesting topics and those they find important in their school tasks. They can also benefit greatly from the consistent habit of promptly debriefing their failures. This research also calls for aspiring innovators to take intelligent risks whenever they evaluate that it is safe to do so.

Limitations and Trustworthiness in the Current Study

This study has both methodological and generalizability limitations. Firstly, the comparison of informal and formal environments was driven by self-report, closed-ended questions, introducing the potential for desirability bias in favour of more enjoyable informal environments. Secondly, a delimitation was that some respondents for the survey were recruited anonymously through social media. Therefore a response rate for the whole sample could not be calculated. However, among the proportion recruited by email, the response rate was 45.4%. Lastly, this study was conducted with Canadian innovators spanning many, but not all, disciplines, leaving reasonable concerns with the generalizability to contexts that may be very different from Canada, as well as unconsidered disciplinary contexts.

Despite these limitations and delimitations, the use of a multidisciplinary mixed-methods approach comprised of 500 surveys and 30 interviews, with good representation across gender, levels of innovator, and disciplinary contexts suggests the trustworthiness of findings. The inclusion of innovators from many faiths and cultural groups provided a diverse pool of perspectives for this study to consider. Additionally, the use of rigour-building methodological practices, including member checking of interviewee responses yielding unanimous interviewee agreement with the aggregated thematic findings, and the use of stricter confidence intervals in the statistical analyses of the survey responses (99% instead of 95%), contributed to the trustworthiness of this study.

Future Research

Additional study of the efficacy of various informal and formal educational contexts would help discover the specific factors (e.g., developed safe spaces, innovation cultures, stability, and "offbeat" contexts) that facilitate the development of innovators and help replicate their successes, potentially leveraging more innovation from aspirants. Specifically, a future study could corroborate the self-report responses of participants with classroom observations. Given that the task value findings of this study implicate overemphasis on evaluation for grades as stymieing innovation, research evaluating the formative assessment alternatives to assigning grades on aspirant capacity to innovate is necessary. As a natural extension of this study, a future comparative case study could examine the qualities of various exemplary formal learning environments to evaluate the mechanisms by which they promote innovation. In a similar vein, experimental research is needed to ascertain the optimal methods for debriefing failure among innovators as an educational opportunity, as well as the optimal way to evaluate innovation to promote growth.

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