Chapter 12
Engaging Students in STEM with Non-traditional Educational Programmes: Bridging the Gaps Between Experts and Learners

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Abstract Aligned with the Reasoned Action Model (Fishbein and Ajzen in Predicting and changing behaviour: The reasoned action approach. Taylor & Francis, New York, 2010), the intention to engage in any behaviour (for example, STEM learning) is influenced by the individual's attitudes, societal norms or cues, and perceived control over the behaviour (that is, self-efficacy). Situated cognition theory (Putnam and Borko in Educ Res 29(1):4–15, 2000) adds that physical contexts and social elements are critical to the learning process and eventual knowledge and skill bases. Our chapter draws on these two theoretical frameworks to present theoretical models and supporting empirical evidence that demonstrate the success of place-based educational programmes (for example, museums, national parks) have demonstrated in promoting student interest, value, and aspiration toward pursuing STEM disciplines (Martin et al in J Res Sci Teach 53(9):1364–1384, 2016). Our work, informed by many others in the discipline, has led to the adoption of a model demonstrating that there are progressively more significant levels of return based on the depth-of-engagement that can be identified for the learners. That is, while virtual experiences show positive outcomes, repeated in-person connections with experts and place-based learning experiences lead to the greatest degree of gains in promoting STEM engagement, interest, attitudes, and achievement.

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12.1 Introduction

In the past decade, considerable attention has been given to expanding educational programming to support Science, Technology, Engineering, and Mathematics (STEM) literacy, interest, and career choice (Braund & Reiss, 2006a; National Science and Technology Council, 2013; Prinsley & Baranyai, 2013). Available evidence suggests that the international focus on STEM education and innovation is driven primarily by the belief that STEM-related competencies are critical to technological and scientific innovation, economic prosperity in the twenty-first century marketplace, and our ability to address many of the challenges that will be encountered by current and successive generations (National Academy of Sciences, 2007; Sahin, Ayar, & Adiguzel, 2014; Wagner, 2008). However, there is considerable concern that current methods of recruiting and preparing people for success within STEM disciplines are failing to generate a sufficient number of individuals to meet the current and anticipated demand for high-quality employees in the STEM workforce (Fox & Hackerman, 2003; Goan & Cunningham, 2006; Kanwar, 2010; Suzuki & Collins, 2009). Stated another way, there is widespread agreement among educators, policymakers, and business leaders that STEM competencies are necessary for economic and societal prosperity, but current educational curricula are failing to produce enough highly skilled workers to fill current and projected vacancies in STEM-related disciplines. For example, a 2012 report from the United States' President's Council of Advisors on Science and Technology determined a need to increase STEM majors by 34% to meet the growing demand (President's Council of Advisors on Science and Technology, 2012).

Efforts to better understand the factors that have led to this projected global shortage of qualified STEM workers focuses primarily on illuminating determinants of learners' decisions to pursue post-secondary STEM degrees, persistence in those programmes, and tendencies to seek STEM employment following the completion of a higher education programme (Bamberger & Tal, 2008; Hiller & Kitsantas, 2014; Sahin et al., 2014). While studies have identified a multitude of factors with the potential to influence individuals' decision to pursue STEM education and employment (that is, informal science learning, mastery experiences, task interest, novelty), available evidence suggests that the establishment and maintenance of interest, fostering confidence in STEM-related skills and abilities, and STEM intentions are often the most potent predictors of persistence in STEM-related disciplines (Chemers, Zurbriggen, Syed, Goza, & Bearman, 2011; Hiller & Kitsantas, 2014; Kotkas, Holbrook, & Rannikmae, 2016; Sahin et al., 2014).

Unfortunately, traditional educational experiences are often ineffective in maintaining student interest in STEM domains across the elementary and secondary school years—especially among students from traditionally underrepresented minority groups (Blickenstaff, 2005; Cici, Williams, & Barnett, 2009; Cici & Williams, 2010; Riegle-Crumb, Moore, & Ramos-Wada, 2011; President's Council of Advisors on Science and Technology, 2012; Willis, 1989). Researchers have referred to the longitudinal attrition in STEM interest among female and low-income students as a “leaky pipeline”—characterized by students withdrawing from pathways in the educational system that lead to STEM careers (Watt, 2016). The continued reduction in STEM career interest and intent that occurs as learners progress through the educational system is most striking when examining collegiate achievement statistics for females and minority students. In 2015, Latino students accounted for 13% and African American students accounted for only 9% (National Science Board, 2018) of all Science and Engineering (S&E) Bachelor’s degrees. A gender disparity was noted within the S&E broad domain as well. Although females received 50% of all S&E degrees in 2015, only 6% were in Engineering, Mathematics, and Computer Sciences (National Science Board, 2018). Finally, although there is evidence of positive growth trajectories in S&E bachelors’ attainment in most categories, the pace is not matching the expected needs projected to meet industry and society demand (National Science Board, 2018).

A variety of theoretical approaches have been applied to address the long-standing gap in positive STEM outcomes for learners—such as the Theory of Planned Behaviour (Ajzen, 1991), Social Cognitive Theory (Bandura, 1997), and Reasoned Action Model (Fishbein & Ajzen, 2010). Review of these models suggests they agree on three key factors that can influence the continued engagement of learners in STEM disciplines. The first primary domain is to raise the interest and affective orientation the learner holds toward STEM topics. The second focuses on ensuring that the learner recognizes that she has the necessary skills and supports to succeed in the domain. Finally, learners need to be able to identify a pathway of pursuing the STEM disciplines (starting with general intention to engage then progressing to actual commitment). We believe informal educational programmes hold great promise to support students in pursuing STEM careers due to the influence that these programmes can have across the educational timeline to inspire positive affect toward STEM disciplines, provide meaningful learning experiences that bolster self-efficacy for STEM, and establish connections with STEM topics and experts who help develop learners’ perceptions of the social utility and opportunities in the fields.

12.2 Individual and External Factors Influencing STEM Career Attainment

Following in the tradition of influential approaches supporting the explanation and prediction of self-generated behaviour (for example, Ajzen, 1991; Bandura, 1997; Fishbein & Azjen, 2010), we agree that initial and prolonged engagement in any self-generated activity follows from the formulation of an intention—or plan—to engage in that activity (Fishbein & Azjen, 2010). In support of this basic theoretical proposition, recent work has demonstrated the considerable power of behavioural intent in predicting learners’ participation in STEM educational programming. For instance, investigations have repeatedly demonstrated that learners with well-developed behavioural intentions focused on STEM degree attainment (plans to major in STEM fields) are considerably more likely to pursue STEM degrees than learners with weak behavioural intentions (Maltese & Tai, 2011; Tai, Liu, Maltese, & Fan, 2006). The development of durable behavioural intentions is the result of the interactive influence of internal attributes of the learner as well as supportive and debilitating environmental factors.

12.2.1 Internal Student Characteristics

Internally, the establishment of goal-directed behaviour is believed to follow from an individual's overall attitude toward the behaviour (that is, is the behaviour interesting or valuable, will the behaviour lead to positive outcomes) and individuals' belief that they have the skills and resources needed to complete the task effectively (that is, perceived behavioural control). These factors are expected to drive behavioural intention such that more favourable views toward the behaviour and increased efficacy beliefs contribute to stronger behavioural intention and future engagement (Montano & Kasprzyk, 2015).

12.2.1.1 Attitudes and Interest

One of the core propositions of our conceptual framework builds upon a sizable body of evidence noting that behavioural intention is fundamentally tied to their perceptions of the behaviour. From a broad perspective, the willingness to engage with educational content over an extended period is impacted by how well the content captures and maintains their interest (Falk, 1999; Hidi, 2006). Therefore, characteristics of the immediate learning environment and the to-be-learned content are critical in capturing the immediate—or situational—interest of learners which often manifests as the experience of positive achievement emotions and the devotion of attentional resources (Braund & Reiss, 2006a; Hidi, 2006). With repeated exposure to high-quality content, interest can develop into a stable personality disposition that is characterized by positive attitudes toward the content area and a desire to repeatedly engage with content from a particular domain (Hidi & Renninger, 2006). Critically, the ability of educators to capture individual interest early in learners' educational progression is critical to entrance and persistence in the STEM pipeline. Empirical investigations have repeatedly demonstrated that students who exhibit early interest in STEM topics—and maintain that interest throughout their educational career—are more likely to pursue and complete degrees in STEM-related disciplines compared to their less interested counterparts (Andersen & Ward, 2014; Maltese & Tai, 2010, 2011; Sadler, Sonnert, & Hazari, 2012).

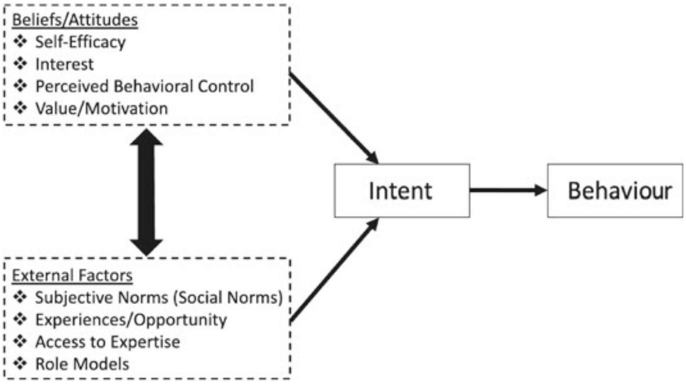

Fig. 12.1 Adapted reasoned action model

12.2.1.2 Self-efficacy

Our conceptual framework recognizes the importance of self-efficacy beliefs in STEM persistence and long-term success. Simply stated, the construct of self-efficacy refers to an individual's belief about their ability to successfully implement the behaviours that are needed to reach desired outcomes (Bandura, 1977, 2005, 2006). Students who are confident in their abilities are better able to organize and implement the cognitive, social, emotional, and behavioural skills required for successful performance within academic settings (Bandura, 1977; Multon, Brown, & Lent, 1991). Consistent with findings in the broader educational literature, recent work has established the existence of a positive association between self-efficacy and STEM persistence and retention. Studies have shown that learners with high STEM self-efficacy exhibit increased interest in STEM-domain and are more likely to develop intentions to pursue training and works in STEM fields compared to their peers who question their STEM-related competencies (Chemers et al., 2011; Lent, Lopez Jr, Lopez, & Sheu, 2008; Lent, Sheu, Gloster, & Wilkins, 2010; Perez, Cromley, & Kaplan, 2014). Collectively, when a student believes she can be successful in STEM activities (for example, through positive learning experiences), she is more likely to approach the STEM discipline, develop a more positive outlook toward the discipline, and remain engaged with the field (see Fig. 12.1).

12.2.2 External Supports and Influences

The behavioural outcomes from the RAM framework are shaped by essential experiences and interactions that occur at the cultural, societal, and interpersonal levels. These external influences directly impact behavioural intent through exposure to the discipline as well as by having the value and importance of the field communicated to the learners. Students who repeatedly interact with positive role models, engage in STEM-related activities, and are shown that they can be successful in STEM fields are more likely to develop positive intent (Bandura, 2005). However, in addition to this, direct influence on STEM intent, external supports, and barriers indirectly influence STEM access and pursuit by influencing the attitudes and beliefs of developing learners.

As outlined in the previous section and illustrated in Fig. 12.1, learners' decisions related to STEM pursuit is based on their interests and perceived efficacy. Unfortunately, research conducted by Braund and Reiss (2006a) indicates many students in developed countries are not interested in science, suggesting a low probability of entry into a STEM-oriented field of study. Research suggests these attitudinal barriers are often linked to pedagogical shifts in STEM teaching and cultural influences (for example, stereotype threat) students experience throughout their educational journey, noting a significant interest decline between primary and secondary education (Braund & Reiss, 2006a; Christidou, 2011; Potvin & Hasni, 2014). As such, the attempt to stave off interest decline and increase positive reception of STEM by connecting learners to informal and place-based learning experiences is expected to impact on eventual intent and behaviour by influencing both the external factors and beliefs and attitudes represented in Fig. 12.1.

Students' perceptions of what may be classified as a STEM career is radically shaped by educational curricula and standards (Finson, 2002; Scherz & Oren, 2006). However, science educators and students report that classroom science learning materials and pedagogical strategies are boring, irrelevant, or outdated and primarily serve those who are already invested in the discipline (Braund & Reiss, 2006b; Goodrum, Rennie, & Hackling, 2001; Sjøberg & Schreiner, 2010). Fortunately, the opposite is true of science education outside of the classroom (Braund & Reiss, 2006a). Whether it be via media, museums, citizen science programmes, active learning curriculum supplements, or nature reserves, STEM-centric education in informal learning environments generates excitement, interest, and persistence in working with contextualized content (Bamberger & Tal, 2008; Braund & Reiss, 2006a; Holmes, 2011; Hiller & Kitsantas, 2014), which can promote greater content mastery and commitment toward STEM careers (Falk, Dierking, & Foutz, 2007).

12.3 Situated Cognition, Social Cognitive Theory, and Constructivism

Situated cognition, or situated learning, among other theoretical bases of knowledge construction, aids in articulating the strengths of exposing students to expert role models and influential environments to solidify beliefs and attitudes toward STEM content. Derived from a foundation of ecological psychology, situated cognition proposes that all knowledge is intertwined within actions, contextualization, and functionality (Barab & Roth, 2006). Not only is the individual–environment interaction a critical component, but situated cognition emphasizes the interconnectedness of content, function, setting, and active participation in learning (Cobb & Bowers, 1999; Greeno, 1997). The situated cognition models often encourage inquiry-based approaches to promote problem-solving strategies and informal reasoning found within scientific endeavours (Bereiter, 1994; Duffy & Cunningham, 1996). Historically, prominent theories of learning also justify situated learning perspectives. Social cognitive theory (Bandura, 1997, 2001, 2002) proposes that social modelling (proxy agency) expands learner control to account for the expertise of others to obtain knowledge and skills, all with the goal to further academic growth. The sociocultural constructivist frameworks aligned with Vygotsky (for example, 1978) that promote learning in a zone of proximal development or scaffolding also place value in connecting learners to real-world problems, interacting with experts in domains, drawing upon social artifacts to support learning, and engaging in shared experiences with peers and educators to frame a foundation of cognitive modelling within a discipline.

The general tenet of constructivism is that learning is an active process of knowledge construction supported by instruction instead of knowledge acquisition via communication (Duffy & Cunningham, 1996; Kintsch, 2009). This general approach encourages students to construct their knowledge and negotiate their interpretation of content to promote refinement of concepts (Cobb & Bowers, 1999). Furthermore, engaging in collaborative learning and situational learning facilitate the necessary meaningful learning and knowledge acquisition required for conceptual change to occur (Novak, 2002).

The active learning paradigm highlighted by Chi (2009) operationalizes primary assertions regarding deep learning presented by situated learning theorists. The paradigm posits that deeper learning is attainable when learners are active in the learning process by personalizing their content understanding, rather than remaining passive observers (Chi, 2009). Specifically, she promotes the utility of the "interactive" learning formats, in which learners engage in multiple interactions as they manipulate their environment, generate hypotheses, and build upon knowledge co-constructed with their partner/mentor (Chi, 2009). Moreover, repeated content exposure with expert support over time enables more profound engagement with content, allowing for significant cognitive associations among the content, functionality, and setting to instantiate (Chi, 2009; Osborne & Wittrock, 1983; Wittrock, 1992). Therefore, multiple exposures to learning in contexts with interactive activities should be most beneficial for deep understanding.

12.4 Successful STEM Engagement Through Informal Learning Resources

To maintain interest and engagement in STEM disciplines requires a steady and developmentally appropriate level of exposure to topics that are often unrealized in traditional school settings. The barriers to fostering student interest and appeal in STEM topics vary widely, but the most commonly referenced issues include (a) lack of expertise by teachers—mainly before middle school (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011), (b) "crowded" curriculum calendars (that is, imposed by the multitude of curriculum standards that overwhelm the instructional day) that limit time to engage in deep learning experiences (Hossain & Robinson, 2012), and (c) funding limitations to support resource-heavy learning experiences (Hossain & Robinson, 2012; Strayhorn, Long, Kitchen, Williams, & Stenz, 2013). While we agree that the standard K-12 school environment is essential for developing and supporting functional STEM literacy, we also recognize the importance of ensuring that teachers and students have options to go beyond standard curriculum offerings by connecting with experts, relevant artifacts, and situationally specific learning experiences that will foster greater awareness, continued interest, and improve the potential for inspiring career pursuit in the sciences and math. We concur with Falk and Dierking (2000), informal education settings environments address the complex nature of learning in cognitive, affective, social, and behavioural manners. This holistic approach to learning enables learners to actively construct their understanding of STEM topics in unique and meaningful ways (Bamberger & Tal, 2008).

12.4.1 Non-traditional Classroom Experiences

A multitude of non-traditional classroom options are available to educators, administrators, and parents to aid in the cultivation of STEM interest, knowledge, and confidence. The highlighted exemplars, we briefly review below are merely representative models and strategies designed to illustrate the potential for bolstering STEM access for more learners within the frameworks of Reasoned Action Model and situated learning that are expected to be adaptable to specific contexts, contents, or developmental ages.

Prominent examples of applying RAM in a way that bolsters STEM learning by incorporating external curriculum, resources, and training to augment standard classroom curricula and structures are programmes such as Project Lead the Way (PLTW) and citizen science programmes. PLTW is a not-for-profit company located in the U.S. that develops curricula for students ranging in ages from early childhood through secondary education, focused on learning STEM topics through real-world applications and problem-solving (Tai, 2012). The stated objective of PLTW is to elevate student motivation and interest in STEM engagement, which will in turn promote math and science abilities (Hess, Sorge, & Feldhaus, 2016; Tai, 2012), which has a long-term goal of shaping the future career choices toward STEM-based careers (Hess et al., 2016).

A central function of the PLTW model is specific and intense training for educators and administrators to deliver the programmed content in their schools, as well as cultivate a healthy STEM ecosystem. Utilized PLTW content creates a cohesive instructional path for students informed through classroom experiences, contemporary research, and collaborative experiences with academic and industry experts

(Project Lead The Way, 2019). Literature reviews examining the efficacy of PLTW indicated increases in student motivation and interest toward STEM content in middle grades (roughly ages 11–14), and secondary school grades (ages 14–18; Hess et al., 2016; Tai, 2012). Furthermore, a multilevel analysis comparing high school aged graduates of PLTW, students declining to join the programme, and students without access to the programme revealed PLTW graduates were most likely to pursue STEM majors (Sorge, 2014).

PLTW is an example of a formal external curriculum augmenting instructional opportunities in classrooms. Citizen scientist programmes are less formally defined and structured but have a similar programmatic goal—to engage learners in real-world scientific pursuits supported by experts within a supported instructional setting. Citizen science programmes utilized in coordination with educational environments empower students to not only construct their knowledge through "doing," but also introduces them to what "real scientists" are outside of classroom experiences. Traditionally, citizen science programmes allow for general public amateur scientists to collaborate alongside professionals and institutions in various fields of research such as astronomy, ecology, and geology (Hiller & Kitsantas, 2014; Snäll, Kindvall, Nilsson, & Pärt, 2011). One example programme engaged preadolescents working alongside experts in the field collecting data on horseshoe crab life (Hiller & Kitsantas, 2014). Naturally, the utilization of citizen science initiatives with students allows for unique informal science education experiences non-accessible within traditional classroom frameworks. Citizen science participation enhances students' mastery experiences in STEM through modelling, scaffolding, and feedback from subject matter experts (Eberbach & Crowley, 2009; Hiller & Kitsantas, 2014). The higher levels of engagement afforded by citizen science involvement have been seen to increase attitudes and interest, in turn positively influencing academic achievement, STEM expectations, and career choice (Brossard, Lewenstein, & Bonney, 2005; Hiller & Kitsantas, 2014).

12.4.2 Place-Based Learning Experiences

Informal and non-traditional learning experiences are critical to promoting STEM career intentions through heightening scientific interest, purposeful participation, and STEM identity development (Friedman, 2008; Michalchik & Gallagher, 2010). Historically, one of the most common ways to supplement student engagement, foster interest, or broaden understanding is to visit an educationally relevant location such as a museum, nature preserve or park, or national historic location (Braund & Reiss, 2006b; Falk, Donovan, & Woods, 2001; Martin, Durksen, Williamson, Kiss, & Ginns, 2016; Rowe, Lobene, Mott, & Lester, 2017). Defined simply, place-based learning is the integration of traditionally "classroom-based" content into a meaningful context in the local environment or community to provide a more interactive and naturalistic setting for student learning (Sobel, 2004). Research has demonstrated that place-based learning can be an effective method for building student engagement, motivation, and achievement. A variety of schools implementing place-based learning curricula—for example, those in large urban areas as well as isolated island communities in northeastern sections of the United States, and rural areas of Australia—have been met with both increases in student motivation and engagement, as well as community support (McInerney, Smyth, & Down, 2011; Smith & Sobel, 2010).

The power and potential for learning in settings such as museums, national parks, and historical monuments is seen by the frequency by which they are referenced as a critical factor contributing to educational advantages observed for children from higher socioeconomic backgrounds. Children who frequently visit museums have fun, parks, landmarks, and other informal learning spaces tend to have a broader educational background before and during their K-12 training (Holmes, 2011). As such, they have a more contextually relevant basis for several domains of inquiry, including STEM topics (Martin et al., 2016). The fundamental advantages afforded to learners who have consistent access to these supplementary informal learning outlets tend to be both broader and deeper representations for the content (Bamberger & Tal, 2008; Holmes, 2011). Beyond mere exposure to more—and often better—content, the experience of learning in museums and parks is that the learning event can be more enduring due to the additional cognitive links that are established for the content presented (Barab & Roth, 2006). That is, learning in situ enables the learner to encode significantly more rich and vibrant representations of the content that form more durable long-term memories.

Research exploring the impact of visiting museums to support STEM learning gains have demonstrated that merely visiting a museum is a positive experience to support interest, learning, and identification with science (Adams & Gupta, 2013). However, learning benefits are more likely to be observed when the time in the museum setting when additional engagement can be supported more fully with prolonged or repeated experience with the institution (for example, as a participant supporting programming at the location; Bamberger & Tal, 2008; Cassady, Thomas, Potts, & Heath, 2017). Structuring the experience at museums (for example, educationally focused engaging activities or questions within the museum space) has also been demonstrated as a critical factor in ensuring that time spent in the museum is maximally effective in promoting learning gains, and students leave the experience with the target content more fully realized (Yoon, Elinich, Wang, Van Schoomeveld, & Anderson, 2013). Similarly, researchers examining class-based field trips or visits to museums are beneficial, but the efficacy of the learning experience was improved when accompanied with post-visit activities or programming (Anderson, Lucas, Ginns, & Dierking, 2000).

One successful nationwide project in the U.S. was the National Park Foundation's "First Bloom" programme. The programme demonstrated that traditionally underserved minority populations could become more invested and engaged in STEM disciplines through repeated exposure to meaningful learning in natural learning spaces (that is, National Parks). The programme involved connecting children from inner-city Boys and Girls Clubs with a nearby National Park through a structured process focused on service learning and promoting sustainable environmentalism. A year-long intervention and evaluation study examining that programme demonstrated that students who were engaged in the programme showed more favourable attitudes toward National Parks and environmentalism, and an increase in their perceived efficacy to "make a difference," and their intent to continue to engage in behaviours that support the environment and/or their National Parks which translated into the identification of behaviours that were supportive of environmental needs (Aurah & Cassady, 2011). Detailed review of the successes in the programme demonstrated that the most substantial gains were noted in the conditions where the children in the programme were engaged in repeated interactions with the National Park representatives (for example, field trips and visits by park rangers to their clubs) as well as active experiences where they were clearly improving and supporting the park (for example, planting sustainable native plants, clearing invasive species that compete with native plants and animals, creating learning experiences for children with disabilities to engage in the parks; Cassady, Ferris, & Kornmann, 2009).

In a related programme focused on adolescents (known as the "Park Stewards" programme), our team evaluated the effects of a place-based multisession programme to promote environmental behaviours among adolescents connected to regionally located National Parks. Across the 20 evaluated National Park programmes reviewed in our work (reaching over 2,800 students), we documented that the "sweet spot" for seeing that level of buy-in with traditionally underrepresented minority students connecting to STEM behaviours between 4 and 6 programmatic experiences—with at least 2 of them in the natural learning space (as opposed to the school; Aurah & Cassady, 2011).

An example of the Park Stewards programme examined varied levels of engagement serves as a model for reviewing the potential of place-based learning within our framework. Students at a high school proximal to Saguaro National Park (within walking distance of the school) in the southwestern state of Arizona in the U.S. participated in a year-long educational experience. The results of that study demonstrated significant differences among students with three profiles of engagement with the National Park learning environment. Core members ($n = 33$) attended multiple learning events led by scientists and rangers from the park (discussing environmental science topics, enacting protections for the saguaro). Partial engagement participants ($n = 15$) attended only one session, and a control group of students from the school who did not attend any events ($n = 37$) were also surveyed at the beginning and end of the academic year. As shown in Fig. 12.2, the critical observation was that a single place-based learning event in the National Park was sufficient to demonstrate an increase in students' attitudes and perceived efficacy to support National Parks and the environment. However, only students who had attended multiple programmatic experiences at the National Park focused on environmental impacts humans can make demonstrated significant gains in their behavioural intent and subsequent behaviour to continue engaging in environmentally supportive activities to preserve National Parks and local natural resources.

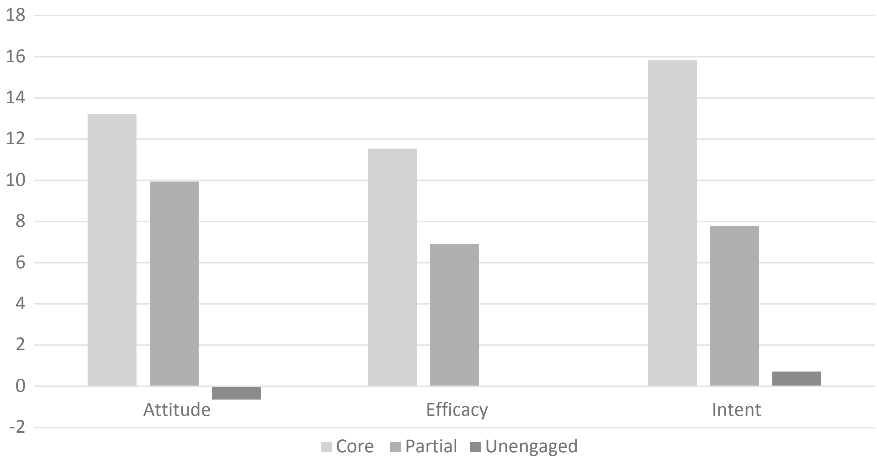

Fig. 12.2 Pre–post percent growth by level of engagement (National Park Foundation Park Stewards Programme)

12.4.3 Electronic Field Trips

Another programmatic approach to informal STEM learning we have been engaged with has been the use of Electronic Field Trips (EFTs), and several "spin-off" iterations of distance-based learning events assisted through technology (for example, Cassady, Kozlowski, & Kornmann, 2008). The primary advantage afforded by EFTs is the ability to connect learners who are isolated from meaningful place-based learning experiences to unique learning environments. While we hold the perspective that virtual access to contextually relevant learning spaces (for example, museum, natural locations) does not afford all the benefits that in vivo experience affords, EFTs do hold promise to support learning for a broader population who do not have immediate access to those locations. In particular, we have noted in prior empirical work that EFTs are effective at capturing the interest of students by inducing what Dewey referred to as their "natural learning impulses" (see Cassady & Mullen, 2006). In addition to sparking interest, research with EFTs has demonstrated gains in student awareness and understanding of STEM topics (for example, formation of the Grand Canyon, geologic science in caves, working in low-gravity environments, migratory patterns of whales) through the use of programmatic elements that encourage exploration of content developed by content and pedagogical experts. In those studies, the critical elements supporting learning and academic gains through distance technology included (a) repeated exposure to the core scientific content and (b) aligning the content of the EFT with classroom experiences by providing lesson support for teachers (Cassady et al., 2008).

While research into STEM learning has demonstrated that learner interest in STEM can be sparked by merely watching videos of scientists (for example, Wyss, Heulskamp, & Siebert, 2012), we advocate for a more structured and strategic approach to virtual learning experiences in STEM. Just as guided field experiences in a museum with a master docent will be connected to stronger learning and understanding (Bamberger & Tal, 2008), having explicit connections among learning goals for students and the virtual educational experiences will make the virtual experience more effective and durable. Exemplary approaches to this have been demonstrated in programmed learning environments that directly tie the academic learning standards or objectives to the programme content, bridging the common gap of expertise in science and expertise in education (Cassady et al., 2008). Teams formed to support this generally have a collaborative process that brings the content experts into connection with pedagogical experts and ensures that the classroom teacher can incorporate the deep and rich science content into their classrooms effectively. Strategies that support this connectivity include providing lesson plan suggestions to complete both before (to provide background context) and after (to have extension learning activities) the planned virtual event(s).

In a series of studies conducted in coordination with the Smithsonian Institution's National Air and Space Museum (for example, Cassady et al., 2017), we confirmed that STEM learning could be supported at a distance provided these structures were in place. The impact on learners was demonstrated in a national sample of middle-grade learners (for example, ages 11–15) who watched a live television or web streaming broadcast of a 30-min. STEM-focused programme (for example, eclipse, science of flight) connecting learners with experts in various museum experts. The student survey contained three subscales scored on a 5-point Likert-type scale focused on positive attitude and interest in the learning event (*interesting, fun*), efficacy related to learning from this modality (*learned a lot, know more than before*), and the intent and desire to engage in future STEM activities (*do another programme, visit Smithsonian Air and Space Museum*). As shown in Table 12.1, the relationships between the three broad subscales (Attitude, Intent, Efficacy) were moderate to high (Tabachnick & Fidell, 2013). In particular, the most significant predictors of student's desire to visit the museum or "do more science" were their ratings of how exciting or fun the STEM-in-30 show was to watch and their statement of how much they would like to view another session. Review of patterns across specific programme offerings provided by STEM-in-30 demonstrated slight differences in attitude, intent, and efficacy. Careful review of the differences demonstrated that while specific topics are certainly more appealing to students (for example, race cars and rockets), the critical features that were most relevant to promoting interest and intent were (a) clarity in programme messaging, (b) connection to their standard science topics (for example, vocabulary tie-ins), and (c) introducing STEM professionals in a more accessible format. Despite

Table 12.1 STEM-in-30 student survey Pearson's r correlations ($n = 68$)

	Attitude	Intent	Efficacy
Attitude	1.000		
Intent	0.714	1.000	
Efficacy	0.606	0.540	1.000
Subscale mean	3.14	3.09	3.56

the programme variations, the overall means of STEM-in-30 participants' responses indicated that their highest average rating was in the domain of 'efficacy,' which was a measure of their perception of having learned from these virtual STEM programmes.

12.5 Conclusion

Our primary conclusions based on the work we have reviewed as well as created is that the utility of non-traditional, informal, or virtual forms of presenting STEM content is centred on three primary guiding principles when attempting to augment traditional methods of delivering STEM content to children and adolescents. First, activating interest and promoting perceived self-efficacy toward the domain is critical to ensuring long-term behavioural intent and engagement. Second, exposing students to STEM experiences that provide an engaging presentation, real-world applications, opportunities to interact with experts, or access to varied representatives from professional STEM disciplines can bolster the positive attitudes (interest) and self-efficacy factors that promote STEM commitment. Third, we identify a continuum of engaging learning activities that recognizes that while all the forms of instructional support or augmentation outlined in this chapter show promise for positive impact, some methods exert considerable influence in behavioural intent and eventual engagement.

When reviewing the first two conclusions, a testable hypothesis is clearly arising. In the revised RAM framework, we centred an earlier portion of this chapter around, we identified the Internal Characteristics (that is, Attitudes/Interest, Efficacy) and External Factors as equitable in their influence on one another as well as behavioural intent. We maintain that these are both key factors, but as we continue to review the data, an alternative model may be relevant. It is possible that the primary influence of the External Factors—at least the ones we focus upon—is almost entirely mediated through Internal Characteristics. That is, while all these supportive events and positive learning experiences are indeed powerful and useful to long-term success, the primary pathway through which this is realized is through the development of interest, positive attitudes, and perceived self-efficacy of the learner (see Fig. 12.3). We maintain that a bidirectional influence is still relevant when considering External and Internal Factors, but the reimagining of the model as displayed in Fig. 12.3 promotes attention to the importance of not only providing positive experiences so that content can be conveyed—but considering the promotion of positive attitudes, interest, and self-efficacy in those programmatic events.

Finally, we believe that the value of varied forms of STEM instructional support is determined by the level of engaged learning prompted for the student, as conceptualized in Chi's (2009) representation of active learning. Specifically, as the level of interaction between the learner and the content increases—with the learner becoming a more central figure in the learning scenario, the level of depth of learning increases. We propose that considering this continuum of engagement can promote learning benefits of informal, non-traditional, and place-based learning experiences.

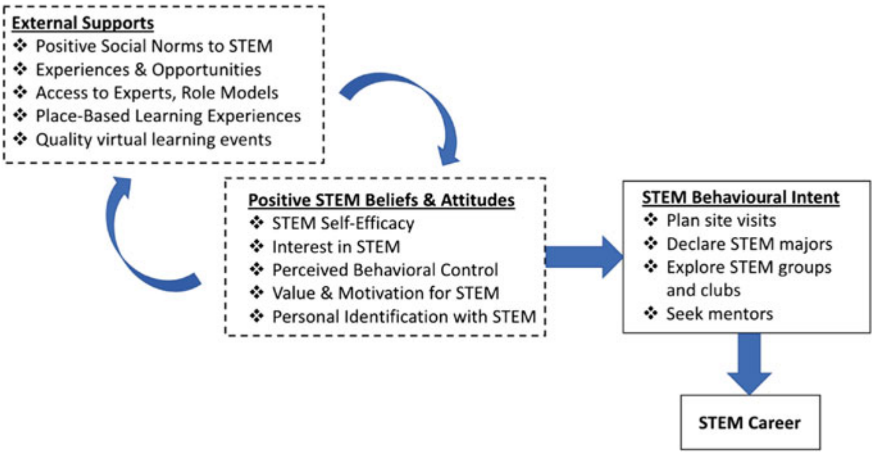

Fig. 12.3 Pathways to promote STEM engagement with non-traditional educational programmes

Based on our work and the work of others, we propose three primary dimensions of consideration when attempting to review the likelihood of meaningful long-term student engagement supported by specific STEM programmes: frequency of contact, "location" of experience, and personal activity. While these dimensions can be separate and vary independently across STEM instructional activities, we anticipate that the learning benefits will be best estimated when examining the interaction among these three. As proposed in Fig. 12.4, we anticipate that the best representation for programme utility will come as an interaction effect between the level of personal engagement and location. While progressively higher levels of personal engagement and situated learning are positive, the greatest gains will be realized as learners are

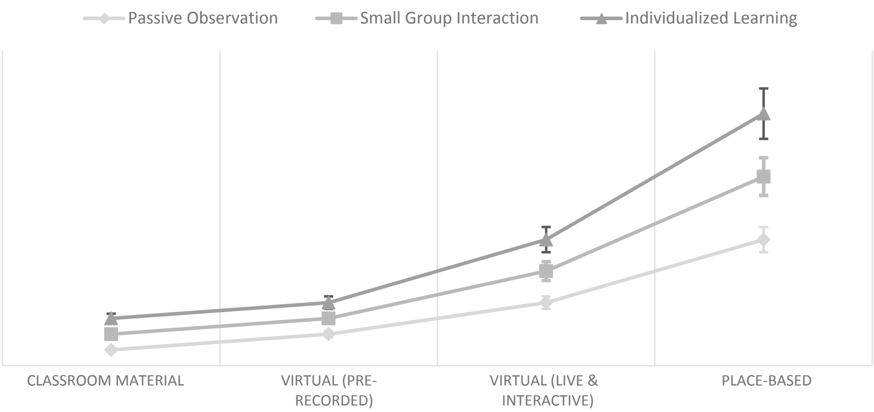

Fig. 12.4 Proposed learning outcomes based on frequency, location, and personal engagement

personally engaged with the content on location. That is, individually driven learning experiences in a STEM-focused learning lab (for example, science camp at a museum) should provide higher levels of long-term STEM commitment than less personally engaged or place-dependent learning situations (for example, online video review of science experiment). We believe the influence of frequency is such that it merely bolsters the effect generated (denoted in Fig. 12.4 with error bars), wherein repeated events strengthen the potential positive impact—provided each repetition has the same value and utility as previous events.

Collectively, we anticipate that as educational support materials expand the delivery options available to teachers and students, greater success in promoting STEM pathway resilience can be obtained. However, continued success in promoting the long-term success of learners in pursuing and succeeding in STEM fields are proposed to be influenced by providing learners with engaging STEM experiences that improve their overall attitudes and beliefs about their own STEM potential. We believe that this is maximized as learners become more directly connected to the disciplines of interest by becoming more personally engaged, directly connected to STEM-relevant places (for example, museums, natural spaces, laboratories), and are exposed to these experiences repeatedly.

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