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Trinity Walton Club: What is its Potential for Promoting Interest in STEM?

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ABSTRACT

Concerns are growing in many countries, including Ireland, regarding an inadequate number of graduates to meet workforce needs in science, technology, engineering and mathematics (STEM) fields. These graduate deficiencies are the result of low student uptake of STEM subjects and courses at post-primary and tertiary level education. Low uptake is partly a consequence of negative student attitudes towards STEM. Many students are losing interest in STEM at an early age due to an inability to see any relevance in their everyday lives. In light of such concerns, a Saturday afternoon club entitled "Trinity Walton Club" (TWC) was established in Trinity College Dublin with the purpose of uniting like-minded students to express, shape, inform and grow their interest in STEM. This club attempted to 'bring STEM to life' through thought provoking content, real world problems, contextualised analogies and projects. This paper describes the background to the TWC, reviews the literature around promoting student interest in STEM and examines initial feedback from participants in the pilot year of the club. The findings of this preliminary study indicate that the TWC has the potential to promote interest in STEM. Many of the recommendations from the literature review about promoting interest in STEM were referred to by participants in their responses.

Keywords: promoting interest, STEM club, STEM retention

BACKGROUND TO THE TRINITY WALTON CLUB

Trinity Walton Club (TWC) is a science, technology, engineering and mathematics (STEM) club which was established in September 2014 and piloted for thirty weeks through to June 2015. The club is based in Trinity College Dublin, Ireland and is a partnership between the College's School of Physics, School of Mathematics and School of Education. The pilot programme was open to young people in their second year (eight grade) of post-primary education, typically aged 13/14 years old. Its intention was to offer members an opportunity to "*unravel the wonders of STEM through thought provoking and appropriately challenging STEM lessons, hands on workshops and laboratory sessions"* (www.tcd.ie/waltonclub/). The club was named after Ireland's only Nobel laureate for Science, Ernest Walton (1903-1995), who was awarded the 1951 Nobel Prize in Physics, with John Cockcroft for 'splitting the atom'. It met Saturday afternoons from 2pm – 5pm and ran for three terms, with each term lasting ten weeks between October and June. The members were called 'alphas', after the helium particles that were critical to Ernest Walton's Nobel Prize winning experiments.

The overarching aim of the initiative was to promote interest in STEM amongst young people and to further enhance their STEM knowledge and skills (Roche et al., 2016). TWC provided additional academic stimulus in three main areas namely physics, mathematics, and a combined stream called technology-engineering. Typically the alphas were split into three groups with twenty participants per session. These sessions were facilitated by PhD students termed 'educators' and were generally fifty minutes each in duration. They offered structured activities that had unique learning objectives and attempted to demonstrate the interconnectedness of STEM in a real world context. The syllabus was developed by a core advisory committee, compromising of academics and the educators of the club. The sessions and activities focused on two main areas of skill development, namely, problem solving and higher order thinking skills. A range of suitable pedagogic approaches, guided the sessions and informed the delivery of the content. The content also complimented the national curriculum and was intended to nurture alphas ability and diligence in mathematics and science. Alphas were also encouraged and supported to partake in national STEM events and competitions.

Throughout the pilot programme, alphas worked collaboratively solving problems, experimenting, designing and building STEM projects, discussing concepts and reflecting on their learning. A range of social activities were organised for the alphas including informal meetings with scientists, technologists, engineers and mathematicians from both academia and industry, who shared their interest and pathway into STEM. After the thirty week programme, the alphas showcased their STEM projects to their families, school representatives and the public. They also received a certificate, acknowledging their commitment to their STEM education and were invited back to continue their involvement in the STEM club in the following school year. It is anticipated that TWC will expand in the future by offering new members the opportunity to take part. The intention is to increase the number of alphas to eighty per year starting from September 2015, and by 2018, to have four parallel programmes running for four different age groups.

All students wishing to participate in TWC had to first pass an entrance assessment and demonstrate an appropriate aptitude before they were offered a place in the STEM club. Although it is a not-for-profit club that is subsidised by Trinity College Dublin and external supporters, a fee of €250 per term was charged per student to ensure the programme was self-sufficient. TWC also offered full scholarships to twenty per cent of members who came from socio economic backgrounds that are underrepresented at university. The 2014-2015 pilot cohort comprised of sixty students, thirty male and thirty female, from thirty different schools in the greater Dublin area.

REVIEW OF LITERATURE

The next section of the paper will review existing literature in the area of STEM education. It will begin by investigating some of the current concerns regarding STEM education, before focusing on students' attitudes and interest toward STEM and how these can be promoted.

Concerns regarding STEM Education

Research shows that despite their importance, the disciplines of STEM have experienced problems in producing adequate numbers of graduates to meet workforce needs in these fields (Hall et al., 2011; Frazer et al., 2010). This has serious repercussions for the Irish economy, particularly in relation to the technology and industrial sectors (Expert Group on Future Skills and Needs (EGFSN), 2008). Although entrance into the STEM fields has grown, this growth is not keeping pace with the overall needs of the labour market (Hall et al., 2011; Hunt, 2011). Concern has also been expressed about students entering higher education without the necessary skills and knowledge to engage effectively with learning in the disciplines of STEM (Hunt, 2011; Treacy and Faulkner, 2015; Treacy et al., 2016).

Recent international comparisons show that Irish fifteen year old students are performing above the Organisation for Economic Co-operation and Development (OECD) average in mathematics and science. In the 2015 Programme for International Student Assessment (PISA), the data for students in Ireland indicated a mean mathematics score of 504, which is significantly above the average across OECD countries (490). The mean mathematics score for Ireland was ranked 13th out of 35 OECD countries and 18th out of all participating countries (Shiel et al., 2016). For science, the mean score of Irish students in PISA 2015 was 503, which was ranked 13th among 35 OECD countries and 19th among all participating countries (Shiel et al., 2016).

However despite such encouraging performances by Irish students in mathematics and science on international comparison tests, concern has been expressed about the declining uptake of these subjects both in the later stages of post-primary education and at tertiary level (Smyth and Hannan, 2006). Such concern can be linked to a number of continuing failures within the Irish education system. For example, at primary level in Ireland, the science curriculum aims to develop both conceptual and procedural understanding among students through an allocation of forty-five minutes per week for infant classes and one hour per week for all other primary classes (Department of Education and Skills (DES), 2012). While these aims are impractical in terms of the time allocated, of more concern is that 16% of students participating in a National Council of Curriculum and Assessment (NCCA) study claimed that they had done no science at primary school (Varley et al., 2008a). After completing eight years of primary education, all students progress to post-primary education in Ireland. This is typically of six years and during this time students complete two State examinations namely the Junior Certificate (lower post-primary) and the Leaving Certificate (upper post-primary). These examinations can be taken at different levels with the most challenging level referred to as Higher and the next level referred to as Ordinary.

Despite the subject's importance, it is not compulsory to study science at lower post-primary level in Ireland. At upper post-primary level, the proportion of young people taking physics and chemistry is low and has shown a decline since the 1990's (Smyth and Hannan, 2006). In 2016, only 17% of Leaving Certificate students took chemistry, and only 14% took physics (State Examinations Commission [SEC], www.examinations.ie). One possible reason for this is that in contrast with many other European countries, not all Irish schools provide opportunities for students to study the sciences at upper post-primary level, with a "significant minority" failing to offer physical sciences at Leaving Certificate (Smyth and Hannan, 2006).

While mathematics is studied by the vast majority of post-primary students, there are also many concerns with the domain such as the low numbers opting to study the subject at Higher level (Prendergast and O'Donoghue, 2014). For example in 2011, figures show that only 45% of the Junior Certificate cohort took the Higher level mathematics' examination. More worryingly only 16% opted for the Higher level Leaving Certificate examination (SEC- www.examinations.ie). While these figures have increased since a reform of the curriculum, there are still many concerns regarding the mathematical ability of incoming university students (Treacy et al., 2016; Prendergast and Treacy, 2017).

There are many reasons cited throughout the literature for such poor uptake in STEM subjects and subsequent graduate deficiencies in mathematics and science. Some of these may be a result of structural problems in our education system such as subjects not being offered in some schools (Smyth and Hannan, 2006) and insufficient class time (Prendergast and O'Meara, 2016). However there is also evidence to suggest that many of these problems may be a result of negative student attitudes towards STEM subjects (Osborne et al., 2003; Papanastasiou, 2000).

Student Attitudes towards STEM

As signalled by the Trends in International Mathematics and Science Study (TIMSS) (1999), student attitudes have an enormous impact on student achievement in a particular subject area (Mullis et al., 2000). Attitudes largely determine what students learn and their willingness to learn. Lindgren (1980) supports this view by stressing the importance of students holding favourable attitudes if learning experiences are to be successful. With reference to mathematics, there is much negativity surrounding the current public image of the subject. In contrast to the *"shame associated with illiteracy, innumeracy is almost a matter of pride amongst educated people"* (Ernest, 1995, p.449). The widespread public image is largely a negative and inaccessible one. This dates back to the age old image of mathematics as difficult, cold, abstract, theoretical and largely masculine (Ernest, 2004). Such negativity consequently has an off-putting effect on the uptake and performance in school mathematics. Statistics released by PISA (2012) showed that just under half (49.6%) of Irish students agreed that they were interested in the things they learn in mathematics (Perkins et al., 2013). In addition, only 40% of Irish students declared that they look forward to their mathematics lessons, while only 37% responded that they do mathematics for the enjoyment (Perkins et al., 2013). Students are reluctant and unwilling to engage in a subject in which they can see little relevance (Prendergast and O'Donoghue, 2014). This is confirmed by the results of an Irish study carried out by Smyth, Dunne, McCoy and Darmody (2006) where 25% of Irish 15 year olds nominated mathematics as one of their least favourite subjects in school.

In contrast interest in science amongst students is generally high, with over 75% expressing enthusiasm for the subject in a study carried out by Smyth, McCoy and Darmody (2004). This finding resonates with that of Varley et al. (2008b) who determined that many students find the science content at post-primary level to be interesting and informative, though difficult at times. The ROSE (Relevance of Science Education) survey conducted in Ireland in 2003/4 found that a majority of 15/16 year old students expressed positive attitudes towards Junior Certificate science and claimed that school science was interesting (Matthews, 2007). However overall attitudes towards learning about biology and chemistry were more positive than attitudes towards physics (Matthews, 2007). Such findings confirm those of other studies where students' attitudes towards physics are not very positive (Varley et al., 2008b). Another finding from the ROSE study was that 55% of Irish students chose the 'extremely disagree' option for wanting to 'become a scientist' (Matthews, 2007). This has implications for Ireland's future social and economic growth (EGFSN, 2008). To combat this problem, studies have identified that stimulating and maintaining students' personal interest is a key issue to address (Beggs et al., 2008; Kuechler et al., 2009; Prendergast and O'Donoghue, 2014). Too many students lose interest in science and mathematics at an early age, and thus make an early exit from possible STEM careers (Sanders, 2009). In a U.S. survey of college students, Beggs et al. (2008) identified various influential factors in their choice of subject and found that student interest was rated as the most important influence. This is supported by another US study carried out by Hall et al. (2011) who found that the top influence on career choice reported by students was their personal interest.

Student Interest

Many definitions are offered throughout the literature regarding interest. Boekaerts and Boscolo (2002) propose that interest is conceptualised as the affect that relates individuals to the activities that provide the type of novelty and challenge that they desires. Hidi and Harackiewicz (2000) describe interest as an interactive relation between an individual and certain aspects of his or her environment (e.g. objects, events, ideas). It can be viewed both as a state and as an outlook of a person, and it has a cognitive as well as an affective component. Hidi (2006) considers interest to be a unique motivational variable, as well as a psychological condition that is characterised by increased attention, concentration and affect. Regardless of definition, the importance of interest was recognized in the late 19th century and not just for career and subject choice. Psychologists and philosophers such as Ebbinghaus (1885) and James (1890) acknowledged that interest made a significant contribution to what people paid attention to and remembered (as cited in Prendergast and O'Donoghue, 2011). Even before that, the philosopher Thomas Reid (1788) suggested that emotional engagement is required for a learner to maintain attention, and therefore to learn anything. In the early part of the 20th century there was a continued understanding of the important role interest played in learning and development. Dewey (1913) maintained that interest facilitated learning, improved understanding and stimulated effort as well as personal involvement.

Dewey's work is supported by more recent research conducted by Hidi and Harackiewicz (2000) who found that interest has a powerful influence on students' academic performance. Del Favero et al. (2007) acknowledge the many studies that have shown the energising function of interest in fostering students remembering and understanding material, and stimulating students' positive attitude towards a topic (e.g. Hidi, 1990; Mason and Boscolo, 2004; Schiefele, 1991, 1998). Hidi and Anderson's (1999) work supports this view by concluding that interest has a profound effect on students' recollection and retrieval processes, their acquisition of knowledge, and their effort expenditure. On top of this, theorists have suggested that interest may be the key to early stages of learning, as well as to differences between expert and moderately skilled performers (Alexander, 1997). When interested in a topic or domain, students are more likely to use higher-order learning thus improving their knowledge (Murphy and Alexander, 2002). This is supported by the findings of Krapp (2002, p. 384) who concluded that "*an interest triggered learning activity leads to better learning results*".

Promoting Student Interest in STEM

Given such importance, it is essential that teachers and educators alike make a conscious effort to promote interest at every available opportunity. However, a study carried out by Weiss (1990) in the U.S. found that only 31% of mathematics teachers declared that they give a heavy emphasis to getting students more interested in the subject. One reason for this lack of emphasis from teachers may be a lack of knowledge about how to systematically develop interest in their classrooms. There are many recommendations on how to do this offered throughout the literature. Firstly, it is important that educators always demonstrate their own interest in the subject matter (Bergin, 1999). The next task is to engage their students in the topic. This can be done using certain aspects of the learning environment, such as modification of teaching materials and strategies, and how tasks are presented (Hidi and Harackiewicz, 2000). Hidi (2006) suggests other means to achieve interest such as selecting resources that trigger interest. These may include games, puzzles, and hands-on activities, depending on the particular topic. However, while such resources trigger student interest, many of them fail to maintain the students' interest over time (Mitchell, 1993).

A study carried out by Mitchell (1993) in the US found that the two main factors in maintaining student interest over time were meaningfulness of task and student involvement. Meaningfulness refers to students' perception of topics as meaningful to their own lives. For example presenting content in more relevant contexts illustrates the value of the subject and makes it more personally relevant for the student. Meaningfulness is effective because content that is perceived as being personally meaningful to students, empowers them and holds their interest (Mitchell, 1993). Involvement refers to the degree to which students feel they are active participants in the learning process. Students are more interested when they learn by doing as opposed to sitting and listening (Prendergast and O'Donoghue, 2014).

Similar to empowering students through meaningfulness and involvement, Del Favero et al. (2007) suggest that several forms of social interaction may also support the development of interest at various stages. This view was supported by Hidi and Harackiewicz (2000) who found that working in the presence of others resulted in increased interest for some individuals. This supports the case for the inclusion of group work and discussion in educational settings. Furthermore Del Favero et al. (2007) determine that problem-solving can often maintain interest by making students aware of gaps in their previous knowledge of a topic, thus encouraging further exploration of concepts and ideas.

THE STUDY

This study explores the potential of TWC for promoting and maintaining interest in STEM. The lessons, activities and resources were all designed and implemented with recommendations from the literature in mind. There was a constant effort to promote interest amongst its members through meaningful and contextualised learning experiences. The educators who facilitated the sessions and activities were encouraged to demonstrate their own interest in STEM. The activities were designed to be as interactive and hands on as possible. For example, the alphas were brought trampolining to explore the variables that control how high one can jump. This offered a conceptual and meaningful pathway to explore several physics and mathematics phenomena. Guided discovery and group work were promoted in each session to allow for students to construct their own meanings and learn from their peers. After activities, there was always time allocated for reflection, allowing opportunity for the alphas to develop their own understanding or discuss concepts further with the educators or their peers. In addition to providing stimulating STEM content through inquiry and project based learning, the sessions and activities often required alphas working in small groups to present and discuss their findings to the larger group. This necessitated the alphas to clarify their own understanding and further enhance their higher order thinking skills. Furthermore the educators employed assessment for learning (AFL) techniques that informed their teaching and offered feedback to the alphas. The educators also facilitated peer and self-assessments. Both of these methods were effective in supporting alphas to develop internal expectations for their work and take ownership of their learning, all of which have been shown to promote interest in the literature.

The design and development of individual lessons, activities and resources will be outlined in detail in a future paper. The purpose of this paper is to evaluate initial feedback from the pilot cohort of alphas to determine whether the TWC has the potential for promoting and sustaining student interest. This feedback was collected through a survey given to the alphas in April 2015. The survey was administered using Survey Monkey and all of the sixty students from the 2014-2015 pilot cohort were invited to respond. It was completed by forty-six participants, signalling a response rate of 77%.

The survey contained ten questions and was predominately qualitative in nature, although there were some quantitative aspects.

For example:

- What do you like most about the TWC?
- If you could change one thing about the TWC, what would that be?
- Please rate each of the three streams (Physics, Maths and Technology - Engineering) using the following 5 point Enjoyment Likert scale. Please tell us what your favourite stream is and why?

The findings of the survey were analysed with a view to answering the following research question: What is the potential of the TWC for promoting interest in STEM? It is important to note at this point that the participants of the study were all voluntary members of the TWC and thus were likely to have an existing interest in STEM. This must be considered when analysing and attempting to draw conclusions from the data.

FINDINGS

The qualitative data from the questionnaires was analysed using a thematic content analysis. Although this study did not involve a large amount of qualitative data, it was decided that two of the authors would carry out the analysis to increase comprehensibility and to provide sound interpretation of the data. A coding scheme was generated based on the main themes which were identified from participants' responses. The final coding scheme consisted of three main codes namely student enjoyment of TWC, knowledge and skill development, and confidence and interest in STEM. Each of these themes will now be discussed in more detail and the main points will be backed up by relevant quantitative data which was analysed using a Microsoft Excel spreadsheet.

Student Enjoyment of TWC

It is clear from the questionnaire data that the majority of participants enjoyed their TWC experience. As can be seen from **Figure 1**, 40 out of 46 respondents (87%) said that they enjoyed the Walton club. There were many reasons for this enjoyment offered throughout the data. Participants liked the *"interactive", "engaging"* and *"fun"* nature of the TWC. The social aspect was very important ("*My favourite thing about TWC was the opportunity to socialise with people my age interested in the same subjects as I am"*), along with the opportunity to engage with '*weekly challenges*', "*experiments*" and "*guest speakers*". They also liked the relationship with the educators which was "*relaxed*" and "*friendly*" and from whom they could see a passion for STEM (*"[the educators] all went on to study science and they speak about it with the same joy as I do which is wonderful"*).

As mentioned previously there are three main strands to the TWC, namely physics, mathematics, and technology-engineering. The data shows that mathematics was the most popular strand with 87% of students

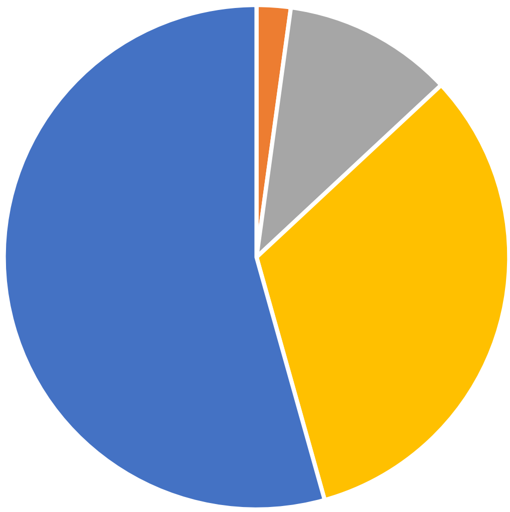

Figure 1. Students Enjoyment of Trinity Walton Club Experience

stating that they enjoyed it, in comparison to 83% for technology-engineering and 70% for physics. Participants found the streams "*interesting*" and "*enjoyed learning about the application of different formulas and theorem's*" along with the *"practical elements and project work"*.

Knowledge and Skill Development

Overall, the majority felt that they have learned a lot of new STEM knowledge through their TWC experience ("*I have learned lots of new STEM knowledge that I can tell my friends and teachers about and amaze them", "I find that I am seeing more STEM in everyday life, and have a better idea of how a lot of things work"*). Some participants mentioned that they could now see the "*interconnections between the STEM subjects and how they should be viewed as a whole"*. For example one student mentioned how *"STEM is very interlinked and one thing leads to another"*.

In one of the questions, participants were asked what skills they felt they had enhanced throughout their TWC experience. The main skill that emerged from the alphas' responses was team-work (mentioned in approximately 66% or 29 out of 44 responses) ("*My teamwork skills have been improved". "I've become much better at working in groups"*). Problem solving was mentioned in approximately 57% or 25 out of 44 responses (*"Using my own initiative to solve problems has really been enhanced"*). Other skills such as thinking outside the box and communicating were also popular responses.

Confidence and Interest in STEM

It is clear from the data collected that students' confidence in their ability to do science or mathematics in school had improved as a result of their TWC experience (*"I expanded my STEM knowledge and this made me more confident to do science and maths". "My confidence has improved and I'm less afraid to ask questions and, if I'm not sure of the answer, I don't mind having a try"*).

Although participants were not asked directly about their interest, the theme did feature in many of the responses. Some alphas said they were more interested in STEM since joining TWC ("*I feel that I have gotten more interested in topics relating to STEM because of my experience in the Walton club*"). This interest has led them to take a different approach to STEM subjects in school (*"In school I listen a lot closer to physics and maths and think about them more deeply"*), in the media (*"I have…listened more closely to the news when there have been articles about science or physics", "I now search science news on Google to hear about the latest innovation in the industry"*), and in everyday life ("*I now view discoveries through a critical lens with an aim to understand how they work rather than simply excepting them without research*"). A general theme was that participants now "*take a bigger interest in how STEM is applied to the world we live in*" and they now "*question everything both in school and outside"*.

This interest has inspired participants to choose STEM subjects in school ("*I would now pick a maths subject over an art", "It has inspired me to choose to physics for Leaving Cert*"), in college (*"TWC has influenced me into considering a course in Computer Science in college", "I would now choose a college course in one of the stem subjects as it has so many career paths"*), and in their future career paths (*"TWC has definitely made me more aware of all the options for careers in the stem area", "I was* *already considering a job in medicine or the likes but now I feel I may enjoy something more scientific…something that needs you to think outside the box!"*).

DISCUSSION AND CONCLUDING REMARKS

The analysis of the initial feedback indicates that the TWC has the potential to promote interest in STEM. Many of the recommendations from the literature about promoting interest in STEM were referred to by participants in their responses. These points ranged from the educators demonstrating their own interest in the subject matter (Bergin, 1999), to engaging in fun and practical tasks and activities. Examples of such STEM activities in the TWC include problem based learning, experimentation, bringing numbers to life, programming, developing apps and building and controlling robots. All of these activities have the potential to stimulate and trigger participants' interest in STEM. In order to maintain this interest it is important that the tasks are meaningful and that students are involved (Mitchell, 1993). Once again these themes are evident from the analysis. The activities used in the TWC are more *"interactive"* and "*hands-on"* as opposed to some participants' experience of school where the main activities are "*textbook reading*", "*listening to our teachers talk up at the board for an hour*" or "*just sitting down and taking notes or doing questions"*. Participants liked that "*everything we do at the Walton club we can relate to real life and things that go on around us"*. Furthermore the review of literature suggested that problem solving and social interaction can help promote student interest (Del Favero et al., 2007; Hidi and Harackiewicz, 2000). It is obvious from the responses of participants that these activities are common place in the activities of TWC ("*I've enhanced my team-work and problem solving because we work in teams a lot and it's good mixing with new people"*).

Other findings from the analysis also highlight the potential for the TWC in promoting interest. Perhaps the most encouraging is that many participants are now inspired to choose STEM subjects in school, in college and in their future careers. This is important given the concerns alluded to in the literature regarding the uptake of STEM at each of these levels. Many participants in the survey declared that they would now consider choosing a STEM subject such as physics in school and college as a result of their experiences in TWC ("*it has inspired me to choose to physics for leaving cert and college as I am interested in it*", "*my opinion of physics which was my least favourite section of the three sciences has completely changed and I feel excited when we start a physics topic*").

Another important finding from the data was that participants can now see the connections between STEM subjects and how they are "*interlinked"*. This is essential as discipline-specific content in STEM should not be divided, but addressed and treated as one dynamic, fluid study (Merrill, 2009). Students need to see the connections between "different subjects" to see their relevance and use in everyday life (Breiner et al., 2012). This will further promote interest not just in the individual subject but in STEM disciplines as a whole. This is important given that those who are interested in a particular domain are more likely to develop the skills needed to operate within it (Csikszentmihalyi, 1990)

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