FOSTERING GLOBAL COMPETENCIES AND DEEPER LEARNING WITH TECHNOLOGY RESEARCH SERIES

STEM OR STEAM: KEY STAKEHOLDERS VIEWPOINTS ON THE FUTURE DIRECTIONS OF STEM

Research & Information Services
Toronto District School Board
October 2017
Report No. 17/18-9
About this Project:

This report is the result of a collaborative project supported by the Council of Ontario Directors of Education (CODE), Technology and Learning Fund, TDSB Teaching and Learning Department-STEM K-12 and TDSB Research and Information Services lead by Research Coordinator Erhan Sinay.


TITLE: Fostering Global Competencies and Deeper Learning with Technology Research Series: STEM или STEAM: Key Stakeholders Viewpoints on the Future Directions of STEM

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ACKNOWLEDGEMENTS

We would like to thank and acknowledge the support of Toronto District School Board Leadership Team:

**Antonio Santos**, Central Coordinating Principal, Toronto District School Board

**Roula Anastasakos**, Executive Superintendent, Research, Organizational Design and Information Service, Educational Partnerships

**Beth Butcher**, Executive Superintendent, LC 1 Leadership-School Effectiveness

**Manon Gardner**, Executive Superintendent, Teaching and Learning, Alternative, International Education

We would like to thank and acknowledge the support and contributions of the following research team members in this study:

**Margaret Douglin**, Research Coordinator, Research & Information Services, Toronto District School Board

**Thomas G. Ryan**, Professor, Faculty of Education, Nipissing University
BACKGROUND AND RATIONALE

Over the last three years the Toronto District School Board (TDSB) has been conducting studies affiliated with STEM (Science, Technology, Engineering, and Mathematics). Some of the topical areas covered have included professional learning in STEM, global competencies, deep learning, and scaling STEM up across the school board. As part of the STEM and Global Competencies research series, educators were asked whether they prefer STEM to remain as STEM or for it to be modified to STEAM (Science, Technology, Engineering, ART, and Mathematics). These educators – who included teachers, administrators, and digital lead learners – were asked this question in survey and interview formats. Each of the question formats yielded similar responses to this question. However, the interview section provided detail as to how individual educators reached their decision showing that their real opinion might be more nuanced then simply choosing a preference of STEM or STEAM.

What is STEAM?

In its essence STEAM is the inclusion of ARTS into the already existing STEM framework. Similarly to STEM, STEAM is a transdisciplinary approach that incorporates a wide variety of skills and knowledge from all of the individual STEAM disciplines in order to problem solve (Yakman, 2008; Winterman & Malacinski, 2015). One of the main mandates of STEAM is to prepare students to solve problems “through innovation, creativity, critical thinking, effective communication, collaboration, and ultimately new knowledge” (Quigley & Herro, 2016, p. 1).

Figure 1: What is STEAM?

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2 Please see the STEM and Fostering Global Competencies and Deeper Learning with Technology Research Series in: http://www.tdsb.on.ca/research/Research/Publications/TechnologyandInnovationinEducation.aspx
How do ARTS benefit students?
Participation in the Arts improves students’ academic achievement, motivation to learn, social engagement, social skills, and helps to generate a positive school environment (Deasy, 2002). Additional studies have shown that students who participate in the Arts programs, especially those from lower social economic groups, achieved higher GPAs and graduation rates compared to students who did not participate (Catterall et al., 2012).

![Benefits of the ARTS for Students](image)

What are the benefits of including the ARTS in STEM?
The inclusion of Arts into STEM generates a variety of benefits. Recent studies have shown that including Arts based teaching in STEM increased student motivation, engagement, and learning of STEM content. (Henriksen, 2014). This finding was confirmed in the work of Rinne and colleagues who showed that Arts training helped with long term retention of content (Rinne et al., 2011).

Additionally, Arts as a component of STEM increase students’ skills, global competencies, and learning strategies. Learning music has been shown to increase visual spatial reasoning skills which can be applied towards STEM (Catterall & Rauscher, 2008). Proponents of the physical and visual arts argue that “artistic expression and principles could assist learners in structuring and organizing ideas, exploring disciplinary and cross-disciplinary connections, and solving scientific problems” (Catterall, 2013, p. 2). Connected to improved problem solving, the integration of liberal arts and language into science resulted in enhanced achievement in science and mathematics (Miller & Knezek, 2013).

Additionally, STEAM provides students who were disengaged with STEM, as a result of fear of STEM or fear of failing in general, a means to reengage with it. Miller (2016) further noted that STEAM in its promotion of divergent and convergent thinking is very effective in generating innovation.
Why STEAM as opposed to STEM?

Review of scholarly literature uncovered findings that highlight how STEAM can improve overall results compared to STEM. Originally, STEM appeared as a response to boost innovative capacity and raise educational performance while also generating a skilled workforce for the future (Bertram, 2014). Catterall (2013), however, felt that using teaching and learning from STEM alone creates an overly narrow approach to problem solving. Currently, calls for a more balanced and inclusive way of teaching have been made that include the perspectives of an even wider variety of disciplines such as design, the humanities, and the arts (Brady, 2014; Connor et al., 2015). STEAM presents the possibility of addressing these varied issues.
How can STEAM programs be implemented in schools?

Fredette (2013) generated the following guidelines for how K-12 schools can implement STEAM:

- It is important that collaboration takes place between teachers of varied disciplines. Teachers across disciplines such as science, visual arts, and music must make efforts to fuse their subject areas together.
- Teachers must model to students the importance of trying new things and removing the stigma of failing.
- Collaboration amongst students and having them work in teams must be encouraged.
- And finally, schools must connect with community organizers to promote a range of modern 21st century jobs that are technology infused and that fall outside the traditional range of professions such as teachers, nurses, and lawyers.
**Figure 5: How to Implement the STEAM Program in Schools**

<table>
<thead>
<tr>
<th>Teacher Collaboration</th>
<th>Community Collaboration</th>
<th>Student Collaboration</th>
<th>Culture of Trying and Failing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Teachers from different disciplines collaborate on learning</td>
<td>• Collaborate with community to expose students to a range of potential future careers</td>
<td>• Provide purposes for student collaboration</td>
<td>• Stress the importance of trying and failing and modelling this to students</td>
</tr>
</tbody>
</table>

What learning and instructional strategies are effective for STEAM implementation? There are multiple strategies that can be used in order to implement STEAM within school boards. It is important that students are allowed to use media/technology in order to solve problems (Miller & Knezek, 2013; Quigley & Herro, 2016). While also being given the opportunity to choose the topics of study, technologies used exploring that topic, the methods of inquiry used, and the means they prefer to communicate the resulting knowledge they derive from it are important (Quigley & Herro, 2016). Additionally, embedded assessment strategies such as self and peer evaluations support STEAM learning (Quigley & Herro, 2016).

In generating assignments for their students teachers must also use various instructional strategies for easier implementation of STEAM. Specifically, teachers must promote problem based learning that uses open ended scenarios and real world problems that are further situated in local contexts (Miller & Knezek, 2013; Kim & Song, 2013). And finally, it is important that teachers integrate varied disciplines in a transdisciplinary approach that uses varied perspectives and potential solutions to problems (Quigley & Herro, 2016).
What are some challenges for STEAM implementation?
Adding Arts to STEM does present some challenges in regards to implementation. Some of these challenges include:

- Teachers not having the expertise in the arts to implement beyond the basic stages of digital/design arts.
- Teachers requiring support from art experts in order to make connections between their content area and the different art forms.
- Difficulty supporting productive collaboration among students (Quigley & Herro, 2016).
- Using a transdisciplinary problem solving approach as opposed to a focus on disciplinary content (Sinay & Jaipal-Jamani, 2016).
RESEARCH RESULTS FROM TDSB STEM AND GLOBAL COMPETENCIES RESEARCH SERIES

Assessing educators view points on STEM compared to STEAM from results collected in the spring of 2016 provided both quantitative and qualitative data. The question of preference of STEM or STEAM was asked in a survey format to adminsisters, teachers, and digital lead learners. Additionally, teachers and administrators were asked this question in a longer form interview format.

Survey Results
Surveys were undertaken for three unique STEM sub groups:

- STEM teachers using coding in their classroom
- STEM teachers using robotics in their classroom
- Digital Lead Learners

Digital lead learners are tasked with training and coaching teachers to maximize their use of technology within the classroom. Survey results for each of these three groups are reported in the following section.

Coding
A total of 142 participants who used coding in their classroom were asked whether they would prefer to see the STEM strategy continue as STEM education or altered to STEAM education. The majority of these respondents answered that they preferred that STEM become STEAM with 73% answering this way. A minority of respondents, 24%, preferred that STEM remains in its present form, while the remaining 3% selected the option “other.”

3 Please see the STEM and Fostering Global Competencies and Deeper Learning with Technology Research Series in: http://www.tdsb.on.ca/research/Research/Publications/TechnologyandInnovationinEducation.aspx
Additionally, 53 teachers who used STEM to teach robotics in their classrooms were also asked whether they prefer STEM or STEAM. As illustrated in Figure 9, the majority preferred STEAM with 64% selecting this option. Of the remaining respondents 32% wanted STEM to remain as it is while 4% selected “other”.

**Robotics**

<table>
<thead>
<tr>
<th>STEAM</th>
<th>STEM</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>64%</td>
<td>32%</td>
<td>4%</td>
<td>53</td>
</tr>
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</table>
**Digital Lead Learners**

When asked the same question of whether they preferred STEM to remain STEM or be modified to STEAM the majority of the Digital Lead Learners surveyed preferred STEAM. As illustrated in Figure 10, more than three quarters of respondents (82%) preferred this. A small minority (10%) said they wanted STEM education to remain the same. Nine percent (9%) of respondents selected “other” indicating that they wanted STEM to encompass even more subjects than STEAM encapsulates subjects such as: social justice, humanities, and language.

![Figure 10: Digital Lead Learners’ Preference of STEM vs STEAM](image)

**Comparison of Groups**

Of the three groups, DLLs felt the strongest about changing STEM education to STEAM with 82% of respondents feeling this way. The lowest was robotics teachers who only wanted to see the change 64% of the time. Conversely, robotics teachers were the group that most wanted to retain STEM in the form that it presently is, with 32% expressing this. Only 10% of DLLs felt that STEM should remain the same.

<table>
<thead>
<tr>
<th>Group</th>
<th>STEAM</th>
<th>STEM</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coding</td>
<td>73%</td>
<td>24%</td>
<td>3%</td>
</tr>
<tr>
<td>Robotics</td>
<td>64%</td>
<td>32%</td>
<td>4%</td>
</tr>
<tr>
<td>DLL</td>
<td>82%</td>
<td>10%</td>
<td>9%</td>
</tr>
</tbody>
</table>

**Interviews**

Interviews were further conducted with teachers and administrators from randomly selected STEM and robotics schools. Schools using coding in STEM were not looked at within these interviews. Teachers were asked whether they would prefer for STEM education to remain as STEM or for it to also include arts and become STEAM. The results were analyzed in two ways. First, a tally of where each educator stands in preference of STEM or STEAM as reported verbally; and secondly, each respondent’s longer form responses are used to provide context and a deeper elucidation of why they selected as they did.

“When I think of STEM I think of some of the past amazing minds of our age - the Da Vincis, the Michelangelos, really if you think about it they were all STEAM.”

Administrator
In total, 8 teachers and administrators were asked the question of whether they want STEM to remain STEM or to become STEAM. The results overwhelmingly favoured a change being made to STEAM with all 7 of the 8 respondents (87%) suggesting this.

<table>
<thead>
<tr>
<th>Group</th>
<th>STEM</th>
<th>STEAM</th>
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<tbody>
<tr>
<td>Robotics</td>
<td>(13%)</td>
<td>87%</td>
</tr>
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A more nuanced look at the answers provided within interview transcripts however presents a more complicated picture. Although respondents did come out in favour of STEAM in their answers, overall, the answers they gave were often not definitive. Many of the respondents expressed either that the title did not matter or that STEM already is STEAM.

Taking this into consideration, the following administrator excerpt shows how this administrator feels that art already exists within STEM in terms of marketing concepts of design and science.

> I think very naturally art should be part of STEM. Even if they are trying to come up with the design for something that flies the best... someone has to market that. Right? And that is an aspect, absolutely of STEM. So I think at the school level we very naturally have infused it even though we are STEM, we do STEAM. (Administrator)

Another administrator expresses that their view is that art is a natural extension of the already existing elements of STEM.

> I think the arts education is really important for students and there is real value in that for all students. I think the emphasis in our society/culture tends to be, “You have got to know how to code and do this and have a computer,” but I think culturally and socially the arts piece is important and it can tie in really well to STEM and the sciences as well. (Administrator)

The final example shows how a teacher feels that the title of either STEM or STEAM is a moot point and what really matters is getting students involved in authentic learning experiences.

> We talked about STEAM as well and for me I think the arts component is very much involved. I think it really doesn’t matter what you call it. I think the main idea is to make sure that people understand that there is this need to get kids engaged in authentic learning when it comes to that whole notion of STEM. (Teacher)
When looking at the question of which is preferred of the two options, STEAM once again appears far more often than STEM when 5 STEM teachers and 5 administrators were queried. However, in this case the results reflect closer to survey results whereas 70% of interviewed educators prefer STEAM and 30% wish for it to remain STEM.

<table>
<thead>
<tr>
<th>Group</th>
<th>STEM</th>
<th>STEAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEM</td>
<td>30%</td>
<td>70%</td>
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Further analysis of the interview transcripts showed more varied and less definitive answers. In some cases, although the respondent indicated that they prefer STEAM, they expressed that the acronyms themselves were simply semantical and only of marginal importance. These findings mirrored what was shown in the robotics interviews.

In the following excerpt you can see that while the participant does agree that STEM should be STEAM his answer is tepid in regards to a name change. In his view STEM does already include arts, but that calling it STEAM just enhances clarity.

> I think the art piece lends itself nicely to doing STEM as well and I think that having it STEAM or STEM I think that it’s not going to make a difference but I think it certainly points out that the arts is not going to be left behind. (Teacher)

Another answer also provides a more nuanced view of an administrator stating they prefer for STEM to become STEAM. Within their answer they show that they prefer STEAM but what really is important is arts and wellness being focused upon within the pedagogy as opposed to a specific name.

> That is a no brainer. I would like to see STEAM [...] I think we need to put a lot of attention on wellness and the arts and when we have wellness and the arts taken care of, I think the curriculum no matter what it is - STEM or STEAM or BEAM it doesn’t matter - is going to fall into place. (Administrator)

Again toying with the language of STEM compared to STEAM this administrator eventually says that though there is significant overlap between STEM and STEAM that in the end STEM is the more accurate designation.

> I think STEM is STEAM, you can call it STEM, STEAM, [and] it’s the same thing. As I’ve mentioned, when I think of STEM, I don’t limit it to the science, technology, engineer and math. That feeds to every subject. For that matter, you can call it... STEAM, but I still think it’s STEM. (Administrator)
DISCUSSION AND CONCLUSION

Although the evidence points towards TDSB educators preferring STEM education to become STEAM education analysis of qualitative data makes the distinction less definite. In essence, the educators interviewed described a longing for dynamic delivery of education that promotes the growth of global competencies, deep learning and 21st century skills. They describe wanting students to become self-driven learners who seek intellectual challenges as opposed to cowering from them. Educators were more interested in these dynamics being met regardless of what the initiative achieving these aims was called.

With this said, a review of the literature provided information that clearly spoke of the benefits of both arts education in general and adding arts education to STEM. Central in the findings was the possibility that by including arts more students, and even more teachers, might be attracted towards STEM. Additionally, adding arts has a variety of positive elements; in particular an ability to reach students who are at greater risk of disengaging from school and dropping out.

Adding arts to the existing STEM education is the recommendation that this report reaches. While not detracting from what STEM presently provides the addition of arts provides more entry points for additional students and teachers to become connected with the pedagogy. Arts inclusion opens the door for even more dynamic inquiry and problem based content, which can only increase the pedagogies overall effectiveness.


