THE GENDER GAP IN SCIENCE STUDIES: COGNITIVE STYLE, NOT COGNITIVE ABILITY*

A controversial explanation for the fact that fewer women than men choose to pursue studies in science, technology, engineering, and mathematics (STEM) has been a supposed gender gap in cognitive ability (IQ). In this paper we offer evidence that it is differences in cognitive style, not ability, that play a role in the STEM career gender gap. We demonstrate how cognitive style impacts student success and suggest how university and college teachers can use these results to increase students' success. The findings in this paper could influence teaching not only in STEM, but also in fields such as psychology, quantitative methodology (QM), economics, and education.

This paper reports a subset of results from a PAREA study (Dedic et al., 2010) that examined many factors (e.g., culture, cognitive ability, teacher support, etc.) potentially influencing the choice of a STEM career. The PAREA study involved 18-year-old students from Sweden and Quebec (N=980[1]), on track towards a STEM career, who completed two in-class surveys. All the Quebec students, having taken appropriate high school mathematics and science courses, were enrolled in the CEGEP Science Program; so we refer to them as "on track" for a STEM career. Similarly, all the Swedish students were taking advanced courses in mathematics and science in preparation for STEM studies at university. The PAREA study found neither differences between Swedes and Quebecers nor significant gender differences in cognitive ability. However, there were significant gender differences in cognitive style. Since no correlation between cognitive ability and cognitive style was found, we conclude that cognitive style and cognitive ability are independent of each other.

[1] The value N=980 represents the number of students whose responses were used in analyses. Outliers and students whose responses were incomplete were excluded from analyses.

SYSTEMIZING AND EMPATHIZING COGNITIVE STYLES

The human brain developed so as to sustain species adaptation to the environment. Humans, adapting to the inanimate environment, developed a cognitive style called systemizing (Baron-Cohen, et al., 2003). Baron-Cohen observed that some babies focus their attention on the motion of objects, as though they are trying to understand how and why these objects move. As children, they often experiment with things in terms of "input→operation→output" and are attracted to activities like playing with blocks. When building a tower, they add a block at the top (input), position it in a certain way above the previous block (operation), then watch the tower fall down (output). They appear to monitor what they are doing by maintaining the input, varying the position where they place the block, and observing the results. It is important to emphasize the deterministic character of these experiments: a particular input and operation systematically generate one particular output. These children are likely to develop a superior systemizing cognitive style, allowing them to deduce rules governing inanimate systems.

However, for survival, our species also adapted to changes in the social environment, developing an empathizing style. Some children focus most of their attention on the people around them, rather than on objects. Their observations do not follow the "input→operation→output" schema. For example: a child observes his mother (input) having a birthday (operation) and being happy (output1), angry because her husband forgot (output 2), upset because her cousin criticized her (output 3), etc. We emphasize two things that distinguish empathizing from systemizing: a multitude of outputs and an emotional involvement by empathizing observers. Children who focus on social interaction in their environment become skilful at understanding other people's thoughts and emotions, and imagining how one would think and feel in social situations. In short, they develop a superior empathizing cognitive style, allowing them to predict behaviours of other people and to respond appropriately to social stimuli.

Although people use both cognitive styles daily in their reasoning, they may not be equally adept at both. Small differences in innate dispositions are probably enhanced through activities and interactions in childhood.

Baron-Cohen's research focuses on low empathizers. He calls sufferers from Asperger's syndrome extreme systemizers, since they lack an empathizing cognitive style. Low empathizers, not understanding others, tend to avoid interacting with people. We have not examined how and whether low empathizers



HELENA DEDIC
Researcher and Teacher
Cégep Vanier

STEVEN ROSENFIELD
Researcher and Teacher
Cégep Vanier

TOMAS JUNGERT
Teacher
Université Linköping (Sweden)

struggle academically, but we suspect that when they are students preparing for occupations involving interaction with people, for instance, when low empathizers take an early childhood education (ECE) program, they may well need special help to be successful. Perhaps teachers of literature commonly face problems with low empathizing students that mirror those faced by teachers of science with low systemizing students.

Some people become low systemizers because they have tended to avoid thinking in terms of experiments with objects and working with numbers. When low systemizers enrol in a mathematics or QM course, they are suddenly forced to rely on a style that they have avoided using and developing most of their lives, and consequently they struggle. The scientific method is increasingly used in many social science domains, so low systemizers may also be struggling with certain aspects of social science courses.

> *While it is certainly important to cover all material, teachers need to figure out how to simultaneously provide sufficient guidance for low systemizing students.*

RESEARCH QUESTION: SYSTEMIZING AND THE GENDER GAP

Baron-Cohen and his collaborators found that, on average, males tend to be better at systemizing and females at empathizing. Science largely consists of understanding and predicting patterns of behaviour of physical objects, so not surprisingly Billington discovered that the majority of students choosing to study the physical sciences were stronger systemizers than empathizers (Billington et al., 2006). Together, these two results suggested a new perspective for re-examining an old problem, the gender gap in STEM studies. Our research question is whether the systemizing cognitive style impacts on student achievement and persistence, and whether this explains the gender gap in STEM studies.

METHODOLOGY

We defined persistence in STEM studies (everywhere else in this paper just called persistence) as an expressed intention to continue STEM studies at university. This intention was expressed in response to a single question posed *after* the deadline for application to a university; hence students' responses were made in the light of knowledge about those applications procedures. Achievement was defined as an average of grades (obtained from participating institutions' records) in mathematics and science courses.

Students were surveyed with a view to assessing systemizing cognitive style as related to everyday activities (e.g., "*I am fascinated by how machines work*"), with responses ranging from "Strongly disagree" (=1) to "Strongly agree" (=4). The surveys were also used to assess: intrinsic motivation (Academic Motivation Scale, Vallerand et al., 1992), which implies engagement in learning because of personal interest and enjoyment in doing it; academic self-efficacy (Motivated Strategies for Learning Questionnaire, Pintrich et al., 1991), which concerns students' self-perceived capability of achieving explicit academic goals and specific results; and anxiety while studying (Academic Emotions Questionnaire, Pekrun et al., 2002).

Drawing on findings from self-determination theory, social cognitive theory, and theories involving academic emotions, we hypothesized that the impact of the systemizing cognitive style is mediated by intrinsic motivation, academic emotions, and self-efficacy. For example, if high systemizers are high achievers and have high persistence, perhaps it is because they are highly intrinsically motivated. Low systemizers might experience high anxiety while studying, which in turn might lead to low achievement and hence to abandoning STEM studies. We also hypothesized that systemizing positively impacts persistence and provides at least a partial explanation for gender differences in persistence. We formulated a theoretical model determining how systemizing relates to achievement and persistence through mediating variables (self-efficacy, intrinsic motivation, and learning anxiety); then we generated and tested it using structural equation modelling.

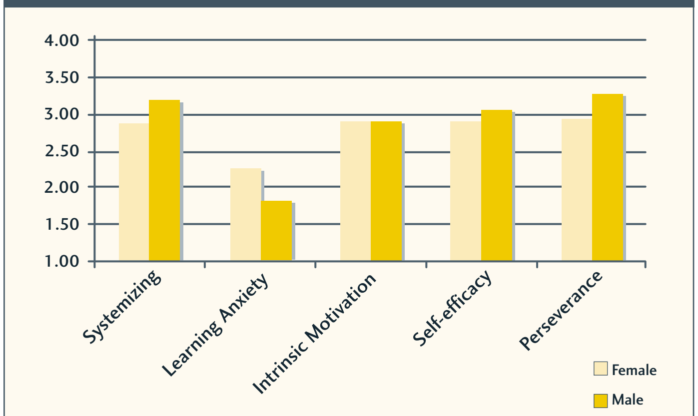
RESULTS

OBSERVED AVERAGES OF VARIABLES

Figure 1 contrasts averages of females and males on several variables. Given that all students in our sample were on track towards science studies, it is not surprising that both females and males claimed to be high systemizers. However, **males were**

significantly higher systemizers than females. All students claimed that they did not experience learning anxiety while studying sciences, but **males were significantly more vehement in voicing this claim.** There was no statistical difference between males' and females' agreement that they were intrinsically motivated to study science. On average, both males and females stated that they have confidence in their ability to study science, but **males were significantly more confident than females.** Similarly, on average, males and females were likely to pursue STEM studies at university. However, **males were significantly more likely to enrol in STEM studies than their female peers.** Since achievement was measured on a different scale, it is not included in Figure 1; but it should be noted that there was **no statistically significant difference between the average achievement of males and females.** It is important to emphasize that no relationship was found in the PAREA study between cognitive ability and cognitive style: being a low systemizer does not imply having a lower ability to study science; low systemizers are just people who are less likely to focus their attention on thinking about systems and how they work. Of course, this lack of systemizing skill does make studying science more difficult for them.

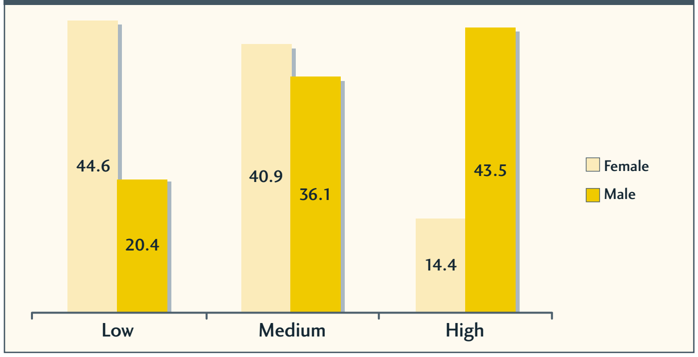
FIGURE 1. PLOT OF AVERAGES



GENDER DIFFERENCES IN SYSTEMIZING

Not only did the averages of systemizing differ by gender, but the distributions of systemizing differed, skewed towards opposite ends of the axis. To measure gender differences, systemizing was categorized into low, medium and high scores, and cross-tabulated versus gender. We computed the Pearson Chi-Square, which indicated significant differences by gender in the distributions of systemizing. Figure 2 shows that 44.6% of the female population were categorized as low systemizers, while only 20.4% of the male population were in this category. In contrast, only 14.4% of the female population were in the category of high systemizers, while 43.5% of the male population were in this category.

FIGURE 2. GENDER DISTRIBUTION BETWEEN LOW, MEDIUM AND HIGH SYSTEMIZERS



TEST OF THE THEORETICAL MODEL

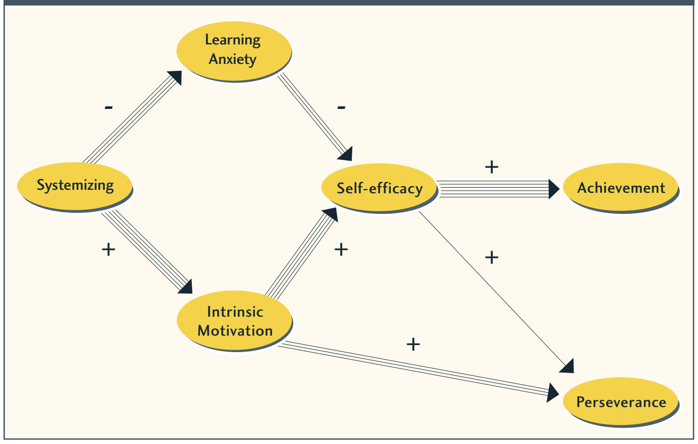
Confirmatory factor analysis indicated that all scales used in this study were reliable. The statistical model that best fits[2] the data is shown in Figure 3. Arrows in this figure indicate causal relationships between two variables (e.g., systemizing causes learning anxiety). The strength of a relationship[3] (scaled from 1 to 10) is indicated by the number of lines in the arrow. A positive sign above an arrow indicates that high values on one variable lead to high values on the other variable. In contrast, a negative sign indicates that high values on one variable cause low values on the other variable. This is like positively sloped lines, which run upwards from left to right, and negatively sloped lines, which run downwards from left to right. For example, the link between systemizing and intrinsic motivation is **positive** and **strong** (+5), while the link between systemizing and anxiety is **negative** and **strong** (-4). This means that the model predicts that high systemizers are **very likely** to have high intrinsic motivation and low anxiety. The link between self-efficacy and persistence is **positive** and **weak** (+1). Thus, the model predicts that students with high self-efficacy **may tend** to persist in science studies. Surprisingly, self-efficacy has a **strong positive** (+ 6) causal link to achievement but only a **weak positive** (+1) causal link to persistence. This result is likely related to the self-efficacy

[2] Pollsters frequently report polls with a "margin of error". Similarly, there is a 4% "margin of error" that the data table predicted by the model differs from the observed data table.

[3] The strength of the relationship describes how much variance in a variable is explained by the model. It shows how strongly one variable (e.g., systemizing) predicts another variable (e.g., learning anxiety).

scale that was used, with most items referring to students' confidence in their ability to learn science rather than to their confidence in their ability to succeed in STEM studies at university.

FIGURE 3. A MODEL OF RELATIONSHIPS BETWEEN VARIABLES



The fact that the above model fits the data well implies that systemizing really directly affects intrinsic motivation and learning anxiety and only indirectly, but positively, affects persistence and achievement. **High** systemizers are likely to experience low anxiety and be **highly** intrinsically motivated and self-efficacious and consequently likely to be high achievers who persist in STEM studies. In contrast, **low** systemizers are likely to be very anxious, unmotivated, and doubtful of their competence, and consequently unlikely to achieve and to persist in STEM studies. Note that this model explains approximately 17% of variance in persistence and 22% of variance in achievement. This indicates that students' decisions concerning their future careers involve many other variables, such as achievement, socio-economic status, parental involvement, labour market, etc., that we have not considered in our model; and this explains the remaining 83% of variance. Similarly, other variables such as study skills may explain the remaining 78% variance in achievement.

Having examined how this model works for male and female sub-populations, we found that the strength of the relationships in this model did not significantly differ across gender. This implies that students, male or female, with the same scores on systemizing are likely to have similar experiences. However, there is a real gap in persistence between high and low systemizers. Proportionately more males are high systemizers; the model therefore predicts that proportionately more males would persist in science studies. In the past, this gap in persistence, often called the "gender gap", has mistakenly been attributed to cognitive ability; but it now appears to be linked to cognitive style. Although a real gap in achievement between high and low systemizers exists, there is no observed gap in achievement between males and females. Low systemizing females may be compensating for their cognitive style by relying on better study skills, an option less available to low systemizing males.

IMPLICATIONS FOR CEGEP EDUCATION

SOCIETAL IMPORTANCE OF THIS RESEARCH

Baillargeon has pointed out that Quebec figures lag below those for member countries of the Organization for Economic Cooperation and Development (OECD) in number of science graduates, as measured by the ratio of degrees earned in STEM studies over the total number of degrees (22% in Quebec versus 28% for the average OECD country) (Baillargeon et al., 2001). Amongst science students enrolled in Anglophone CEGEPs in 2003, only 49.8% of females and 56.4% of males pursued STEM studies at university after CEGEP graduation. Recent reports indicate that the percentage of female engineering students in Canada declined from a peak 20.6% of all engineering undergraduates in 2001 to just 17.1% in 2008. Both findings indicate that a gender gap still exists in Canada and Quebec. Low STEM graduation rates present our society with a serious problem, because success in educating more scientists and engineers, the next generation of innovators, is necessary to drive a successful economy and maintain social programs (like our pensions). Our results may be the key to understanding why many students, particularly females, opt out of STEM studies; and this could open doors to remedies.

CEGEP TEACHERS' CHALLENGE

— Helping low systemizers to learn

Low systemizers are people who shun daily activities that would give them practice at recognizing patterns, figuring out how things work, scientific reasoning, etc. When they enrol in a calculus or QM or economics class, their skills at performing such mental tasks are likely to be low, and consequently they experience a high cognitive load (Kirschner et al., 2006). A high cognitive load can occur in any field, depending on the learner's prior knowledge and skill. For example, non-athletes learning to ski often face frustrations. They must simultaneously focus their attention on all parts of their body, on moving them in the right sequence, and on doing it all very quickly. Their brain cannot process all of this information, so they suffer cognitive overloading. In contrast, athletes hearing a short demonstration and explanation of how to perform a parallel turn can rely on already well developed mind-body coordination to learn this task quickly. Kirschner and his colleagues recommend that, in general, college teachers develop instructional designs that decrease cognitive load. They recommend very explicit and direct instruction: "[W]hen dealing with novel information, learners should be explicitly shown what to do and how to do it." For example, they show that students who were guided to study worked-out examples actually learned more than students who were just given problem sets. At the CEGEP level, low systemizers may also benefit from detailed modeling of thought processes in class and from having access to worked-out examples. However, Rosenfield (2005) reported that over 50% of mathematics and science teachers in Anglophone CEGEPs believe that the single most important responsibility they have is to "cover" all material, something they find easiest to accomplish by straightforward lecturing. While it is certainly important to cover all material, teachers need to figure out how to simultaneously provide sufficient guidance for low systemizing students. College administrators may need to provide professional support to teachers in the form of both training and resources, as well as new kinds of student assistance in learning centres.

Teachers could aim at creating a collaborative learning environment. Students observing their peers coping with anxiety while in a collaborative setting may learn from the experience.

— Increasing intrinsic motivation and decreasing anxiety

Our model shows how systemizing influences persistence through its relationship to intrinsic motivation and learning anxiety. Low systemizers, males and females alike, are less likely to be intrinsically motivated and more likely to experience anxiety. We did not test particular instructional designs in the context of this study. Hence, we only offer suggestions as to how to increase students' intrinsic motivation or decrease their learning anxiety. In writing this paper, we brainstormed for an analogy to best explain cognitive load theory. As scientists, we constructed several apt analogies involving computer memory or computer programming, but we decided that many of our readers would better relate to a skiing analogy. Instructors frequently use analogies to help students understand novel concepts. However, analogies drawn from domains where students have no prior knowledge may increase confusion. Many different analogies can be used to enhance rather than to hinder the understanding of any given concept. We believe that the use of analogies from domains in which students have knowledge and a natural interest is a winning strategy on two counts: it may enhance student cognition and it may also promote student interest in learning our subject. We recommend that teachers invest time and energy in creating a bank of analogies, drawn from different domains, for every difficult concept. Having such a collection readily available, teachers may use them to spark intrinsic motivation amongst more of their students.

Learning anxiety is always present when a learner is facing a novel task. Teachers could aim at creating a collaborative learning environment. Students observing their peers coping with anxiety while in a collaborative setting may learn from the experience. Teachers can also "bring anxiety out of the closet". By referring to some concepts as "difficult to master" or as "anxiety provoking", teachers may help students to accept that a low level of anxiety is normal. Teachers can also encourage students to seek their help when the students experience either excessive anxiety or anxiety that does not seem to abate.

ECE PROGRAM TEACHERS' CHALLENGE

— Educating graduates to develop systemizing skills in young children

Baron-Cohen showed that two-month old babies display their innate preferences as systemizers or empathizers. These preferences influence children's choices of activities. Some children enjoy playing with inanimate objects and figuring out how systems work and other children simply do not. Gredlein and Bjorkhead (2005) demonstrated that interventions in small children's play can increase the use of systemizing. They simply provided direct instruction of "what to do" and "how to do it" and observed that children who initially avoided getting involved in certain games became enthusiastic participants after such instruction. Simpkins (Simpkins et al., 2005) showed that early childhood experiences guide choices of subsequent academic trajectory. Thus, increasing all students' interest in science careers and closing the gender gap in STEM education may require thoughtful intervention in young children's play. We hope that teachers involved in the ECE program will consider developing this idea further with their students.

CONCLUSION

Our research shows that the level of a student's skill at systemizing affects achievement and persistence in science programs and probably has a similar impact in many social science, commerce, and professional courses that involve scientific reasoning/mathematical content. Thus it is important for CEGEP teachers to be aware of their students' systemizing and empathizing styles, either by direct observation or by using a survey instrument. It is also important for a second reason, namely that teachers' own styles influence how they teach, and yet their students will have different sets of styles. Such insight could inspire teachers to adapt their instruction to help low systemizing students (or the opposite in the case of teachers/courses/classes that tend to emphasize empathizing). In the long term, we hope that those amongst us who teach in education programs such as ECE can create and teach curricula that focus on developing both systemizing and empathizing cognitive styles so that future generations of Quebecers will have more career options available to them and not suffer the current damaging impact on self-efficacy and motivation, and hence on achievement and persistence, of a low systemizing style.

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Helena DEDIC was born in Prague and she obtained her MSc in Astrophysics from Charles University. Starting in 1974 she spent thirty-five years teaching Physics at Vanier College, won the Teaching Excellence Award at Vanier in 1996 and in 2009 she was named a Scholar in Residence there. She has been an education researcher and Adjunct Professor in the Department of Education and Education Technology and full member of the Center for the Study of Learning and Performance at Concordia University since 1992. She served for several years as a member of the Commission de l'enseignement collégial and on the Scientific Committee of CAPRES.

helena.dedic@gmail.com

Steven Rosenfield was born in Montreal. He obtained his BSc Honours Mathematics from McGill University, and an MA in Mathematics from Brandeis University. After teaching for two years at Concordia University he began teaching at Vanier College in 1973, where he won the Teaching Excellence Award in 2008 and, that same year, was named a Scholar in Residence there. He has been an education researcher since 1989, an Adjunct Professor in the department of Education and Education Technology and a full member of the Center for the Study of learning and Performance at Concordia University since 1991. He served for several years as the Cégep representative on the Mathematics Action Plan Committee, a provincial committee examining problems in Anglophone sector mathematics education. He has served on the executive of the Quebec Association of Mathematics Teachers since 1997.

rosenfis@vaniercollege.qc.ca

Dr. Tomas Jungert teaches psychology at the Department of Behavioral Sciences and Learning at Linköping University, Sweden. His work covers areas in group psychology and social psychology in education. His thesis focused on student motivation and self-efficacy in a longitudinal, comparative study of four cohorts of engineering students. He is currently involved in a project about motives to study to become a teacher, and a cross-cultural project with its focus on the declining enrolment in STEM studies that explores the importance of study motivation, self-efficacy and cognitive style in understanding the phenomenon.

tomas.jungert@liu.se