FOSTERING BETTER ENGAGEMENT AMONG MALE AND FEMALE STUDENTS IN THE PHYSICS LABORATORY

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Teachers see it every day and research shows it more and more clearly: male and female students engage differently in their studies and in class. Since, in general, female students respond more easily to academic requirements in a traditional learning context, we wanted to see if a new approach in the physics laboratory would have a favourable impact on the engagement of both genders, and in particular on male students.

Within the scope of a *PAREA* research project[1] conducted at *Collège Shawinigan* over a two-year period, we studied the impact of two types of experiments in the physics laboratory on the engagement of students in the Natural Science program: traditional closed experiments in which the process is directive and defined by the teacher; and open experiments in which students participate more actively in the different stages of the activity.

As seen in Herron's classification (1971) provided below, traditional closed experiments consist of stages defined and developed by the teacher, often in the form of protocols that students can follow much like a recipe (Case 2). The most closed approaches (Case 1) consist of demonstrations carried out by the teacher in front of the class. Here, it is the teacher who performs all the steps in the experimental process. In open experiments, which correspond to Case 3, students formulate their own hypotheses starting from a situation presented by the teacher and they develop their own protocols, such that the process draws on their capacities, their autonomy, and depends primarily on their engagement.

The most open approach (Case 4) consists of a project chosen and conducted by the students. This is the case, for example, with certain Comprehensive Program Assessment activities.

Wanting to find out the extent to which the type of experiment impacted male and female students differently, we looked first at whether the types of engagement differ according to gender in traditional closed experiments. After that, we wanted to know if, in fact, open experiments favour the engagement and learning of both genders.

For our study, data was collected from 31 female and 26 male students in the Natural Science program at *Collège Shawinigan* (N=57). These students were observed in the physics laboratory during the winter 2008 session (Electricity and Magnetism course) and the fall 2008 session (Optics course) in experiments conducted in teams of two. Two semi-directed interviews, one with a group of 8 male students, the other with a group of 7 female students, completed this qualitative data collection. These interviews aimed at validating or elaborating on findings that were based on observations. The students who were invited to participate were representative of just about all the different forms of engagement that we will introduce later in our model. Questionnaires completed by the students and their teacher also provided data on some of the dimensions of engagement, such as interest and feeling of competence.

So what exactly is the question when we say we are studying engagement? What reality does this concept cover and what are its manifestations?

CLOSED AND OPEN EXPERIMENT METHODS, ACCORDING TO THE ROLE OF THE TEACHER AND STUDENT
(Inspired by Herron, 1971)

STEPS OF THE EXPERIMENTAL APPROACH	CLOSED EXPERIMENT METHODS		OPEN EXPERIMENT METHODS	
	Case 1	Case 2	Case 3	Case 4
Identify and describe the purpose of the experiment	Teacher	Teacher	Teacher	Student
Formulate the hypothesis of the experiment	Teacher	Teacher	Student	Student
Develop the experimental procedure	Teacher	Teacher	Student	Student
Analyze and draw conclusions	Teacher	Student	Student	Student

[1] The research report entitled, *Étude de l'engagement selon le genre dans les laboratoires de physique* was published in 2009. It is available in all Quebec CEGEPs and it can be viewed online on the *Centre de documentation collégiale* website.

THE CONCEPT OF ENGAGEMENT AND ITS MANIFESTATIONS IN A LABORATORY SETTING

In an academic context, the idea of engagement evokes involvement, personal investment and interest in school; it is also associated with persistence and effort devoted to studies. (Fredricks *et al.*, 2004; *CSE*, 2008). Often confused with the concept of motivation, that of engagement has a distinct meaning however.

Academic motivation is generally described as a psychological state created by a desire or a need when faced with a learning situation. Intrinsic or extrinsic, it is students' motivation that leads them to become engaged, that is, to take action and to remain focused on accomplishing an activity. Thus, engagement can be seen as the behavioural manifestation of the psychological state of mind called motivation (Astin, 1984, quoted in *CSE*, 2008, p. 9). In terms of behaviour, engagement can be seen as a global way of responding to situations in which people find themselves. Since the form that engagement takes is strongly determined by the situation, our study attempted to identify the behaviours of male and female students in response to the two types of laboratory activities that would be presented to them.

Most authors agree now that school engagement involves various dimensions. This multidimensional character is reflected in the Anglophone literature we consulted, where a student's engagement is a phenomenon defined in three ways.

Behavioural engagement

This refers either to behaving positively at school, to following the rules and accepting the standards, or to diving into the learning tasks while manifesting attention and active participation in class.

Emotional engagement

This refers to the student's positive reactions (interest, openness, etc.) with regard to learning activities, the subject matter, the teacher or the other students.

Cognitive engagement

This relates to the quality and degree of mental effort invested in understanding and realizing a task. It involves the desire to accept challenges. One piece of the research measures cognitive engagement by looking at students' self-regulating strategies, that is, their uses of strategies such as planning, validation, evaluation, and regulation when completing a task. On this point, a qualitative distinction underlines the fact that students who resort to in-depth learning strategies are cognitively more engaged than students who resort to superficial learning strategies.

According to research so far, there is no doubt that these three forms of engagement are closely linked and that it is difficult to study them separately. In some ways they overlap; in others they are complementary. Whatever the case, a number of researchers interested in student engagement in class pay special attention to cognitive engagement. To paraphrase one observation by Corno and Mandinach (1983): while students may seem to be attentive and to be spending a lot of time on the task (*behavioural engagement*), while they may seem to be stimulated and interested (*emotional engagement*), they are not necessarily making a mental effort or learning anything at all (*cognitive engagement*). In our study therefore we made a special point to go beyond misleading appearances in order to focus on the different degrees of cognitive engagement that can be detected from one student to the next throughout the realization of an experimental task.

> *Our study was […] particularly careful to go beyond misleading appearances in order to explore the various degrees of cognitive engagement that can be detected from one student to another all through the realization of the experimental task.*

Because the act of thinking is not directly observable, to describe the *degree of cognitive effort* presupposes making inferences based on a number of manifestations. In the laboratory, observing what seems to be a moment of deep reflection for a student seems to be insufficient, even though persistence can prove to be significant in itself. However, in the context of the physics laboratory, the content of the exchanges among the students and the nature of the questions each one asks (of one's partner, of the teacher, etc.) are the first clues pointing to the degree of cognitive engagement. At its highest degree, students' cognitive engagement shows that they have a clear understanding of the objectives of an experiment and that they are proceeding in a strategic manner. At the opposite end of the scale, cognitive disengagement can be detected in a student whose attention, comments, and behaviour veer away from the experiment in progress.

Although the students' talk was of particular interest to us, many behavioural traits came to complete our observations. In this regard, the moment when teams face a difficulty proved to be particularly revealing of the degree of cognitive engagement. How does each one manage at that moment to overcome obstacles and to stay engaged in the task: in an autonomous way and by first drawing on their own personal resources or by relying on easy assistance? Do we see the students rely on themselves to a search for written information (in the protocol when one is provided, in their notes, in their physics manual, on the Internet, etc.)? Do we see them manipulating the set-up or using the data collection system in search of meaningful data? Do we see them discussing with team members or with other teams, asking themselves appropriate questions? Or instead do we see them, hands raised, regularly questioning the teacher or the technician present in the laboratory and continually making a minimal effort to think for themselves?

Ultimately, we asked ourselves if male and female students carry out experimental tasks in distinct ways, if they encounter different difficulties and overcome them by giving priority to specific resources. We wanted to know if they reach comparable degrees of autonomous thinking and, once this is known, if the open laboratory favours better cognitive engagement from both genders.

Given that the dimension of cognitive engagement in the laboratory was a main concern of our research, the affective dimension remained interesting, but in the background. The main aspects of emotional engagement that we considered related to the interest and to the feeling of competence that the students had for the field of study or for the activity.

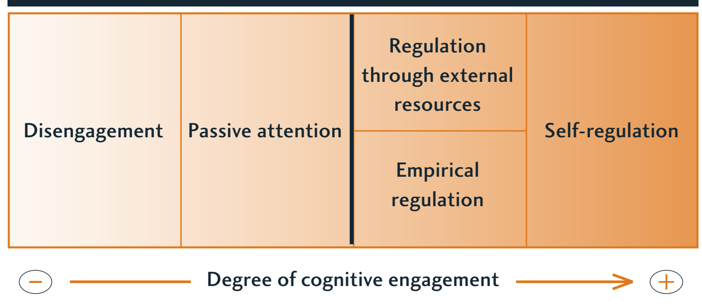
A FIRST CONTRIBUTION OF THE RESEARCH

OUR INSTRUMENT FOR THE CLASSIFICATION OF MODES OF ENGAGEMENT IN THE LABORATORY

When we put all our observations together, for each student observed we were able to define their mode of engagement in the physics laboratory. For us, students' *modes of engagement* are characterized by the degree of cognitive effort that they generally put into doing an experiment, and by the type of resources to which they turn, especially when they have problems to solve. To support our study, we developed the model presented below. This instrument made it possible for us to fine-tune our observations in the interpretation of the behaviours manifested in the laboratory. It also served as a recording instrument for categorizing the observed students. Elsewhere, at the end of this article, we will indicate how teachers could use it in their interventions with students.

Our interpretation model was inspired by the works of Corno and Mandinach on cognitive engagement (1983-1985). We designed it in the form of a schema in such a way as to enable us to situate a student's mode of engagement. In this model, cognitive engagement in the laboratory increases in strength and autonomy as we move from categories on the left to those on the right. Thus, at the extreme left we situate zero degree of engagement, that is, disengagement.

FIRST VERSION OF THE MODEL
FOR INTERPRETING MODES OF ENGAGEMENT



Passive attention therefore describes the 1st degree of engagement. This mode of engagement refers to a passive approach where the act of thinking is 'short-circuited' so to speak. It can be observed in a situation where students follow the instructions provided and carry out the task while investing a minimum of cognitive effort.

According to our model, disengagement and passive attention, located on the left, are both distinct from the three other modes of engagement located on the right. In these three modes, students actively participate in *maintaining their engagement* during the experimental task done in the laboratory. For us, maintaining one's engagement consists of taking measures to overcome the various types of difficulties encountered in accomplishing a task. We can therefore state that for each of the three engagement modes located on the right, students maintain their engagement by *regulating* their procedures when faced with obstacles in order to bring the experiment to term. We therefore adopted the term 'regulation' to underscore the *active* nature of students who are engaged in one of these three modes, but also to emphasize the fact that students self-regulate to *maintain* their engagement while the experiment is in progress.

From left to right within these three modes that call for regulation, cognitive engagement varies from its lowest to its highest degree. At the highest degree, students who self-regulate when accomplishing a task mobilize first and foremost their personal cognitive resources, and they do this in a strategic, indeed metacognitive, manner (planning, validation, evaluation), which is not the case for students who regulate their actions with the help of external resources or in an empirical manner. In these last two modes of regulation, students do not achieve the same degree of cognitive autonomy as students who are capable of self-regulation. In the external resources mode of regulation, students who complete a task maintain their cognitive engagement with the help of available resources (teammate, teacher, protocol, manual, etc.). In the empirical mode of regulation, students use materials (set-up, data collection system) to obtain the necessary information to follow the procedures, without necessarily engaging in a reflective process that is as refined as students who are capable of self-regulation.

Where this model differs from that of Corno and Mandinach is particularly within the modes of regulation using external resources or by empirical regulation. According to us, and contrary to what Corno and Mandinach suggest, there is no progression of cognitive engagement when a student goes from the mode of regulation by external resources to the empirical regulation mode: rather there exists a continuum and a progression toward cognitive engagement within each of these two modes.

For us, maintaining one's engagement consists in taking measures to overcome the various difficulties encountered in accomplishing a task.

Based on our understanding of the phenomenon, each of these two modes can call for cognitive engagement in varying degrees, from a low degree to a higher degree. For instance, students who maintain their engagement while questioning the teacher on how to carry out a task (regulation by external resources) make far less use of their own cognitive resources than if they ask the teacher to validate their own ways of proceeding or, even better, if they ask their teachers what they think of a hypothesis that has come to their minds during the experiment. For another example, students who maintain their engagement by manipulating the set-up (empirical regulation) using randomized trials and without observation mobilize to a much lesser degree their own cognitive resources than if they proceed by trying different approaches and by reflecting on the results so obtained.

Thus, in our model, not only does cognitive engagement in the laboratory increase and become more autonomous from left to right, but it also varies within a single mode of engagement based on how resources are mobilized.

INTERPRETATION MODEL FOR STUDENTS' MODES OF ENGAGEMENT IN THE LABORATORY

Disengaged	Attentive	Active	Autonomous
Disengagement	Passive listening	Regulation through external resources	Self-regulation through external resources
	Passive during set-up	Empirical regulation	Empirical self-regulation

(−) Degree of cognitive engagement → (+)

Another point is to make a distinction between the sections in the upper half of the schema and those of the lower part. In the lower section, we find students of any mode whatsoever who rely mainly on empirical resources, whereas in the upper section we could situate students who mainly use external and theoretical resources.

As others have observed before us, students can alternate from one mode of engagement to another just as well within a single learning task as among different tasks (Corno and Mandinach, 1985; Lee and Anderson, 1993, Fredricks *et al.*, 2004). Also, in observations that it is possible to make in the physics laboratory, it seems important to make a distinction between what we called a *secondary mode of engagement* and a *dominant mode of engagement*.

When we take an inventory of significant behaviours that we observe in the laboratory (asks a question, looks in the manual, manipulates the set-up, talks about unrelated matters, etc.), it is possible to note in the same student manifestations of a single mode of engagement at times and sometimes of several. Consequently, we called *secondary modes of engagement*, those which a student manifests occasionally, and the *dominant mode of engagement* that which a student manifests most often.

SECOND CONTRIBUTION OF THE RESEARCH: OUR MAIN FINDINGS

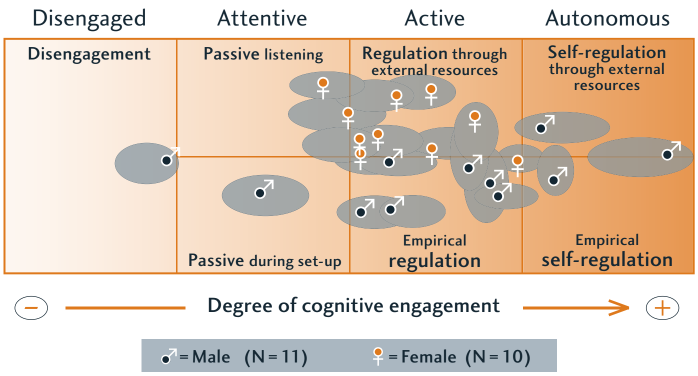
Our observations point to two major findings:

- behaviours of engagement vary according to the gender of the student;
- the degree of cognitive engagement varies according to the type of laboratory.

ENGAGEMENT IN THE CLOSED LABORATORY

The schema that follows shows the modes of engagement usually observed among male and female students during an experiment in a closed laboratory. Each of the ovals represents a student. An oval can cover two modes, sometimes more; the dot inside the oval represents the dominant mode.

MODES OF ENGAGEMENT OF MALE AND FEMALE STUDENTS IN THE CLOSED LABORATORY



Characteristics of engagement among females

In this type of laboratory, female students rely predominantly on external resources to maintain their engagement: they ask many questions of the teacher and other teams, they follow the protocol very closely, they consult their course notes, etc. However, is this *apparent* engagement (positive behavioural engagement) *really* cognitive engagement? As it is, the questions asked by more passive female students indicate weak persistence and a need for direction, essentially a short-circuiting of cognitive effort. The more thoughtful questions from students who are more engaged cognitively do not show any less need to be validated. Thus, in a search for an immediate solution, not one of these students manages to reach the highest level of cognitive engagement (self-regulation).

In interviews and on questionnaires, female students recognize that they have little interest in and a weak feeling of competence for the subject and laboratory activities. Because most of them are considering contingent university programs and are pursuing elevated objectives for success, they do what it takes to remain engaged in realizing the task. In fact, they generally achieve better results than male students in the physics laboratory.

Characteristics of engagement in male students

Although supported by a directive protocol, male students are naturally at ease with the empirical resources they have at their disposal. Inclined to research on their own and reticent to question the teacher, they proceed by trial and error, debate among teammates with regard to the set-up, and are at ease using the materials. This is hardly surprising, given their marked interest for the field and the feelings of competence that they manifest in the laboratory.

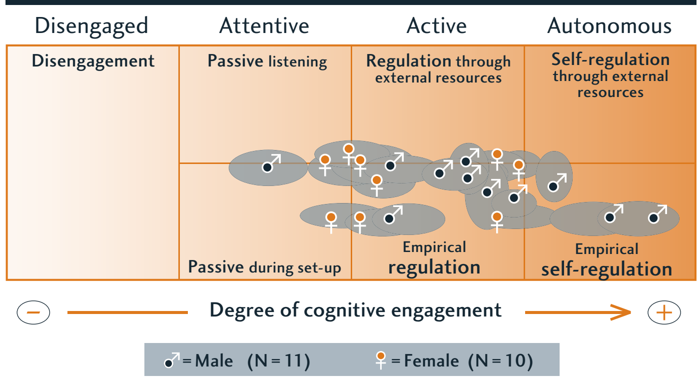
Nevertheless, cognitive engagement varies considerably from one male student to another. Those who have the necessary cognitive resources to work things out on their own achieve self-regulation. At the other end, male students who are less at ease find it difficult to maintain their engagement. Lacking the means to progress on their own in the task, they are slow to turn to their last resort: the teacher. A matter of pride? When interviewed, none of the male students hid from it:

- *It's more fun to research by yourself. When you reach the point where you have to ask a question, it's a sign that things are really not going well. It's because you have exhausted all the resources.*
- *You do not want to look like you're sucking up to the teacher either.*

ENGAGEMENT IN THE OPEN LABORATORY

The schema below presents the modes of engagement observed during an open laboratory.

MODES OF ENGAGEMENT OF MALE AND FEMALE STUDENTS IN THE OPEN LABORATORY



At the outset we note that empirical regulation is preferred by both genders. This student behaviour is a response to being asked to accomplish a task without a protocol and, exceptionally in this experiment, without help from the teacher.

We also note that no student remains disengaged and that the coercive nature of the task entails higher cognitive engagement. As one student put it:

> *In open laboratories, you have no choice but to understand, because […] there is no protocol. One way or another, you come to conclusions. […] It forces you to.*

On the whole, the students indicated a higher level of interest for open laboratories. The reasons most often given are the possibility of selecting the subject of study, of thinking for themselves, and the pleasure of facing a challenge.

Male students overwhelmingly appreciate this type of experimentation, regardless of their academic performance. They find in it the latitude of searching on their own, of trying without the constraints of a protocol.

Female students of good academic standing also prefer this type of experimentation because it gives them the opportunity to understand on their own, to feel more involved and to become accomplished. On the other hand, less gifted female students express some reservation when faced with a process that falls more on their shoulders, uncertain that they will be able to complete the experiment on time. Our observations also showed that the students who are the least cognitively engaged in open laboratories are, most of the time, female.

Regardless of preference, both male and female students recognize that their cognitive engagement is greater in open laboratories, thereby corroborating our own observations.

THIRD CONTRIBUTION OF THE RESEARCH: SOME PATHS

Viau (2009) emphasizes that cognitive engagement as well as persistence are better indicators of motivation to learn than pleasure. Although the open experimentation that we studied was not preferred by all, it appears that it has a positive impact on the cognitive engagement of the greatest number of students. Less directive than closed laboratories, open laboratories put male and female students in situations that compel them to learn, confronting students with challenges that solicit their autonomy of thought and action.

It is using this logic that two physics teachers at *Collège Shawinigan* adopted an open laboratory approach with their Natural Science students over the past two years. When we asked them about their initiative which was carried out on the margins of our work, they drew conclusions from their experience that overlapped with those that we reached in our research. They cover three points.

A PROGRESSION TOWARDS AUTONOMY

The first laboratories, indeed the first sessions, should be more closely supervised and they should demonstrate explicitly to the students the stages of the scientific process, a method for working and the way to rationalize a problem. If they are exposed prematurely to an open structure, many students will not discover these aspects on their own.

At the opportune time, the objective pursued by using the open approach should be explained to the students. Over a period of weeks, the teacher can propose experimental tasks that are increasingly open, the most open of which being based on a single starting question (for example, on what does the oscillation period of a pendulum depend?) and leading students into longer processes (for instance, two laboratory periods of two hours each).

Our observations show that the resources on which students rely in order to overcome a difficulty play a central role in the quality of their engagement. Indeed, two of these resources deserve special attention. On the one hand, with regard to empirical resources, the female students all manifested their difficulties with using the data collection system. For them, far from being a tool, it represented more of an obstacle. When they were interviewed, they suggested producing a guide to facilitate its use. On the other hand, teachers represent a resource for them to such an extent that we will discuss their influence in the next point.

> *Our observations show that the resources on which students rely in order to overcome a difficulty play a central role in the quality of their engagement.*

"OPEN" INTERVENTIONS

To be consistent with the aims of the open laboratory, the interventions of teachers must avoid short-circuiting the students' cognitive engagement. This presupposes the adoption of a non-directive role, that is to say directing and supporting the students' questioning rather than providing them with answers. Made explicit to the students, this approach will empower them in the situation, it will incite female students to engage more actively in their process and it will make male students be more receptive to receiving help. As one of them put it:

> *Perhaps it is not so much the answer we want when we ask a question, but maybe just a way to find the answer.*

In our view, the teacher must first penetrate the students' reasoning, then help them to reflect and to search. The two teachers we met confirmed that they achieve greater success when they resort to questioning techniques. At its highest level, questioning can support metacognitive abilities that are the foundation of self-regulation by, for example, helping students to plan out a task ("What is your objective?" "How will you approach a certain stage?") or to validate their process ("How do you know that you are on the right track?", "Do you see other possibilities?").

> *[...] open laboratories put male and female students in situations that compel them to learn, confronting students with challenges that solicit their autonomy of thought and action.*

LESS AUTONOMOUS MALE AND FEMALE STUDENTS: SOME DIFFERENCES

Because students in Natural Science pursue success objectives that are generally elevated, they rarely demonstrate motivational difficulties. The issue here is rather to help them achieve greater cognitive engagement (moving toward self-regulation) and to maintain this engagement. This is particularly true in the case of less autonomous male and female students who need to be supervised more closely, without which they tend to disengage. Open experiments presuppose being vigilant and staying ahead of these students, males in particular who, as we know, are less inclined to ask for help.

With this in mind, what distinguishes male and female students is perhaps of less importance. When facing difficulties, the central issue is less a matter of gender than it is of personal approach: choosing the right moment to intervene, asking a question that destabilizes or validates the process, requesting a later check on how results are progressing, or redirecting a team towards appropriate resources, etc. The two teachers we met confirmed this: follow-up in the open laboratory is more demanding. However students do benefit from immediate feedback on their process.

In matters of support, the model we have designed can be useful for appreciating the quality of students' cognitive engagement by reminding us to pay attention to the questions they ask, to the means that they use and to the resources they rely on or that they prefer in order to manage by themselves. It can also be used to take stock with individual students, to provide them with feedback, and to encourage them to engage in self-evaluation.

CONCLUSION

Male and female students engage differently, but the impact of the open laboratory on both genders shows that the same pedagogical approach, by its very nature differentiated, can provide a strategic – and democratic – answer to the diversity in our classes.

Others have also reflected on factors that favour engagement. It is easy to discern in other recognized educational practices of similar type (*Carrefour de la réussite au collegial*, 2009), certain characteristics of the open laboratory. These practices face students with high expectations, they present them with intellectual challenges, they are based on active learning and collaboration, and they are focussed on the realization of projects.

When male and female students are engaged in a laboratory activity such as in a project, are they merely constructing a scientific interpretation of the world? Or, are they not also gaining access to a deeper knowledge of themselves?

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