

# t.p.é\*

Une collection d'outils pour (s')initier à la publication en éducation et valoriser la transformation pédagogique

\* transformer et publier en sciences de l'éducation



Ces outils sont organisés en trois volets :

- accompagner / structurer pour les accompagnant-es
- rédiger pour les équipes enseignantes débutant en recherche-action
- s'enrichir / ressources une série de références et de guides

Ils ont été développés par la Chaire recherche-action sur l'innovation pédagogique de l'Université Paris Saclay et l'institut Villebon - *Georges Charpak*, en collaboration avec l'UQAM, et sont le fruit du travail de Marine Moyon, Frédéric Bouquet, Jeanne Parmentier, et Martin Riopel, et d'Emmanuel Ahr pour l'outil EVA.

L'exploration, la conception de la charte graphique et la mise en forme des outils ont été réalisées par Dalva Rospape et Marie Jouble.

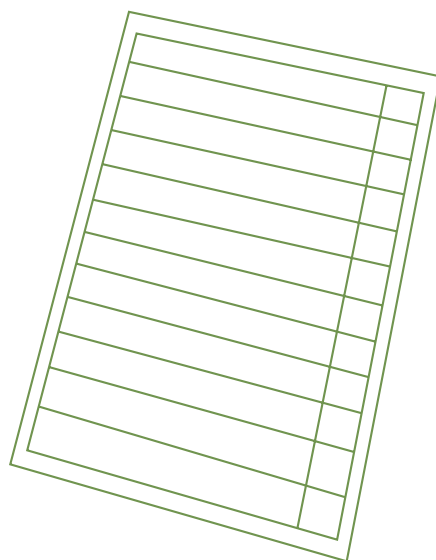
Retrouvez tous les outils sur :  
<https://cep.villebon-charpak.fr/tpe>

## → s'enrichir / ressources

### glossaire

Cet outil s'adresse aux personnes enseignantes porteuses d'un projet de recherche-action.

Il vise à faciliter la rédaction du cadre théorique ou conceptuel. Quelques concepts incontournables y sont expliqués.





→	sommaire du glossaire	EN
	attitude	17
	blended learning	18
	engagement	20
	agentic engagement	22
	embodied cognition	26
	embodiment	27
	flipped classroom	28
	interest	29
	interest development	35
	faculty learning community	37
	mathematics anxiety	38
	metacognition	39
	motivation	41



L'accompagnement appartient aujourd'hui aux formes coopératives ou collaboratives dans lesquelles la relation y est conçue dans une recherche d'égalité gommant les dissymétries et résulte du rejet actuel de toutes les formes relationnelles dissymétriques.

La relation s'établit donc sur cette base où accompagnant et accompagné sont à la fois semblables (en raison de leur appartenance au genre humain) et différents (parce que n'occupant pas la même place sociale).

Dans un accompagnement sous forme de dispositif, on peut concevoir une typologie de la relation interpersonnelle graduée d'une relation fonctionnelle (qui satisfait une nécessité, remplit une fonction pratique), à une relation conviviale (où transitent et se vivent des émotions, des affects) – et d'une relation coopérante (support à une expérience de réorganisation d'une partie de ses conceptions) à une relation heuristique (support d'une expérience ouvrant sur une saisie inédite d'éléments). On peut donc échelonner les différents stades relationnels :

Le côte à côte, juxtaposition d'individualités plus ou moins closes sur elles-mêmes, ne s'engageant peu ou pas dans la relation.

Le face à face, relation se construisant sur la base d'un investissement souvent unilatéral de convivialité, de confiance, et d'activités visant à instaurer une compréhension unilatérale de la situation.

Le travail avec autrui dans lequel la relation est fondée sur une communauté d'objectif, un diagnostic partagé de la situation et du travail à engager, une reconnaissance mutuelle, et la nécessité co-ressentie de définir explicitement leur fonctionnement relationnel. La confrontation de points de vue différents n'y est plus redoutée, mais acceptée, voire recherchée. La compréhension de la situation est déployée au profit de celui qui y est impliqué.

Le faire ensemble : c'est l'intelligence de la situation qui fait cohésion.

Estime de soi, confiance en soi, en l'autre et dans le projet qui les rassemble, reconnaissance mutuelle et appui sur les talents individuels créent un haut niveau de synergie, chacun assumant sa part de responsabilité, chacun existant comme individu singulier. Les activités incluent des modalités communicationnelles accordant plus d'importance à la subjectivité, sous l'angle des émotions et des affects, des croyances et des convictions et du pari d'une créativité exacerbée par la diversité des points de vue.

Le faire ensemble est un enjeu sociopolitique qui engage des valeurs, touche aux rapports de pouvoir dans les institutions et, par extension, aux modalités de partenariat. Or la crispation sur les objectifs et résultats à atteindre entrave l'aménagement de cadres relationnels adéquats. Car la mise en place des liens, à travers la confiance, le crédit, la considération, ne se décrète pas et s'établit dans le temps. Par ailleurs, si la confiance est le premier ingrédient de la relation, celle-ci fonctionne moins sur le mode empathique que sur le mode réflexif. Paradoxalement, la modalité réflexive contribue à la construction de la relation en intégrant la distanciation par rapport à ses propres points de vue (représentations, préjugés, idées, croyances...) et ouvre à l'expérimentation de nouvelles façons de voir ou de concevoir. Ainsi l'autonomisation de la pensée (capacité à élucider, critiquer, évaluer, choisir, décider...) est-elle un préalable à toute coopération. Susciter, encourager, affermir l'autonomie, loin d'être incompatible avec une visée de coopération, en serait même la condition.

Le « processus opportunités » s'intéresse à la manière dont les ressources mises à disposition pour agir/apprendre sont converties en « capacités d'action » (ou d'apprentissage) et aux facteurs facilitant ou entravant cette conversion. On parle de facteurs de conversion positifs ou négatifs (Sen, 2009 ; Fernagu Oudet, 2016c). Ils se traduisent par « Ce qui facilite (ou entrave) la capacité d'un individu à faire usage des ressources à sa disposition pour les convertir en réalisations concrètes. Ils sont liés à l'individu et/ou au contexte dans lequel il se trouve. Ils permettent de transformer les ressources en possibilités effectives » (Fernagu Oudet, 2012).

- Le « processus liberté » permet d'identifier ce qui contraint ou libère les dispositions à apprendre ou à agir (Fernagu Oudet, 2016a). On s'intéresse à la manière dont les conversions se traduisent en réalisations (ou accomplissement) et sur les facteurs de choix pesant sur l'orientation de ces dernières. L'attention se focalise sur la « capacité de choisir », car Sen (2001, 2004) a mis en lumière le fait que « l'accessibilité [d'une ressource] ne peut se résumer à une question de moyens et d'opportunités à disposition des personnes mais comprend également le rapport que ces personnes entretiennent avec ces opportunités, leur marge de manoeuvre, et plus généralement leur liberté de choix » (Zaffran, 2015, p. 30). On voit combien les capacités offrent un prisme plus large que les compétences pour étudier les capacités d'action ou d'apprendre des individus, car elles combinent ces dernières à la question des capacités de choisir. Nous verrons plus loin que le développement de la capacité à s'autodéterminer participe à cette construction.

Peu de travaux portent aujourd'hui sur l'identification des facteurs de conversion ou sur celle des facteurs de choix. Ces facteurs génèrent pourtant des variations importantes dans la mobilisation et la conversion des ressources, et donc des configurations différentes selon les individus en termes d'accomplissements (Zimmermann, 2011 ; Coste, 2013 ; Lambert & Vero, op. cit. ; Vidal Gomel & Delgoulet, 2016) – qu'ils soient réels, potentiels ou attendus.

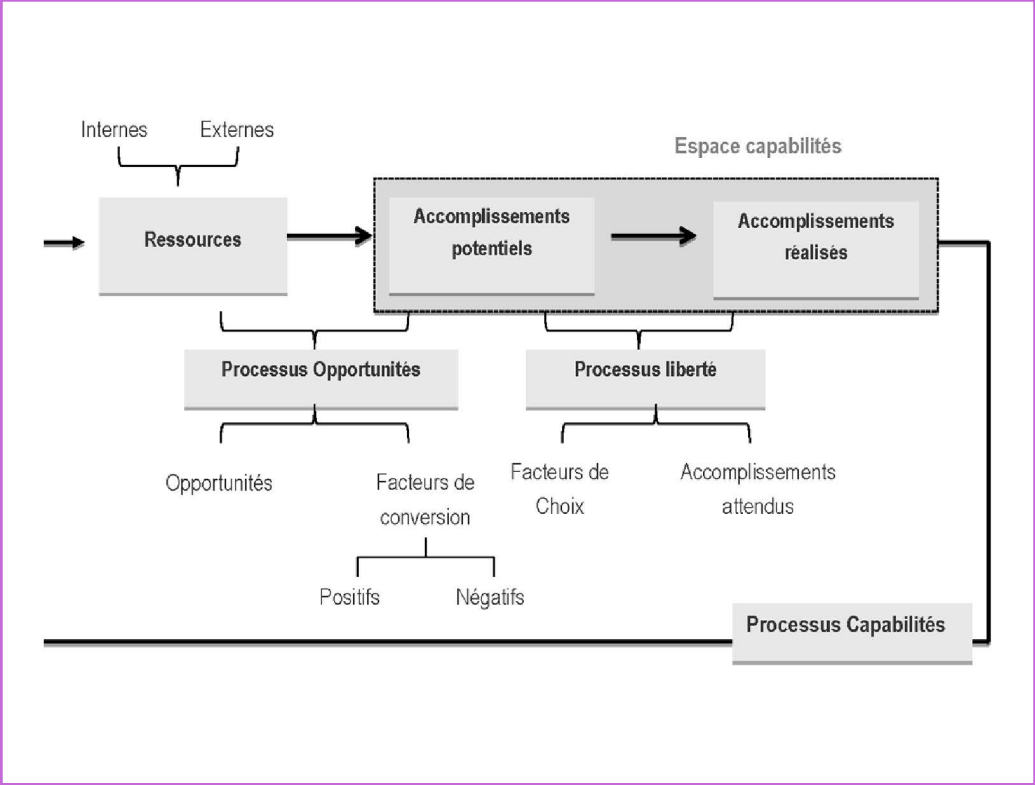
- Le « processus capacité » résulte de l'interaction des deux premiers processus et permet d'apprécier l'espace des possibles, le « pouvoir d'agir » au sens sénien. Ce dernier peut se définir comme le rayon d'action effectif d'une personne (Clot, 2008 ; Corteel & Zimmermann, 2007) et relève de l'articulation de la capacité d'agir (ou d'apprendre) et de la capacité de choisir (Fernagu Oudet, 2016c). Ce processus permet d'appréhender la manière dont les individus sont mis en « capacité d'accomplir » (ou de réaliser) et de se développer. Il permet de s'interroger sur la qualité des environnements de travail qui sont proposés et in fine sur la manière dont ils se montrent capacitants.

Il est admis qu'un environnement capacitant est un environnement porteur de capacités. En toute logique, il s'agit donc d'un environnement susceptible de contribuer au développement du pouvoir d'agir des individus (Fernagu Oudet, 2012, 2016 ; Falzon, 2005, 2013). Cette notion interpelle les organisations sur le plan de leur capacité à faciliter les conditions de l'apprentissage ou de l'action.

# environnement capacitant approche par les capacités

Fernagu, S. (2018). Les capacités au prisme de la capacité à s'autodéterminer : Les Clubs de dirigeants de PME. Formation emploi, 142, 231-254.

fig. 1

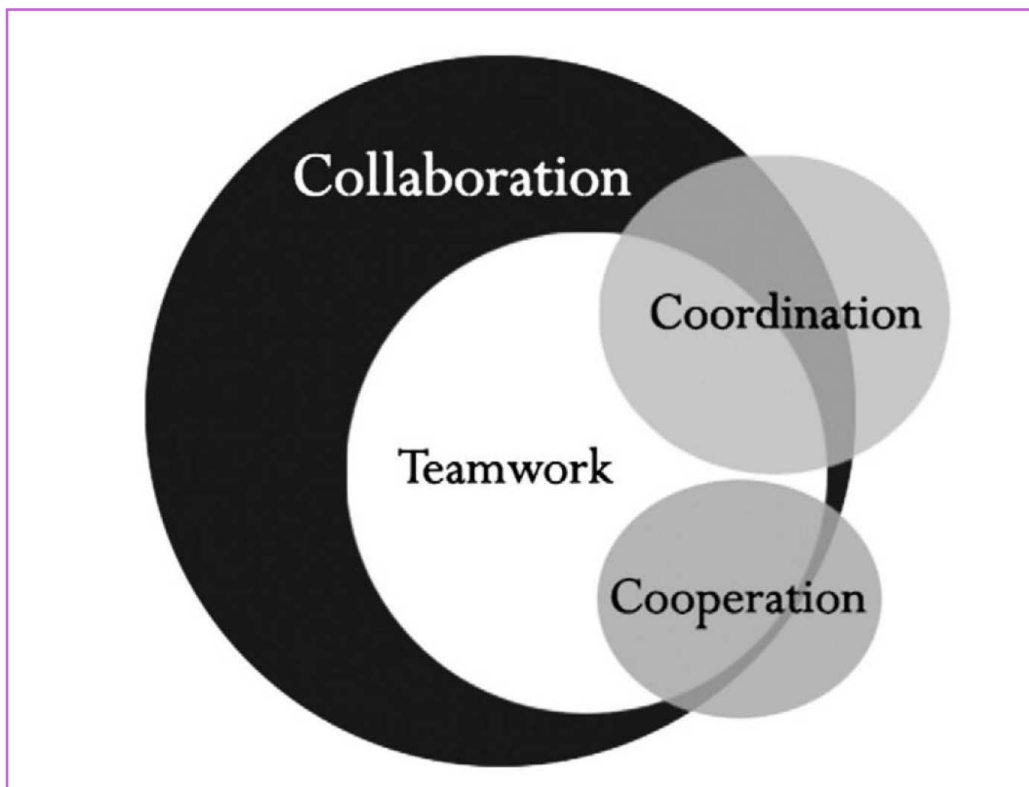


“Dans son sens commun, la collaboration signifie simplement « travailler de concert avec quelqu'un d'autre pour élaborer en commun une solution négociée et consensuelle » (Dubois, 2009, p. 370; Thomas et al., 2007). Depuis les échanges d'idées et les réflexions entre pairs, au concept d'interdépendance sociale en passant par les travaux sur le leadership, la définition de la collaboration n'est pour autant pas encore stabilisée (Raynault, 2018). Utilisé depuis longtemps dans de multiples disciplines, ce concept en apparence simple traîne avec lui un flou conceptuel le confondant notamment avec le travail en équipe ou la coopération (Raynault et al., 2021). Il en est de même pour la collaboration appliquée à l'apprentissage. Depuis le début du XXe siècle, de nombreuses études traitent des apports de la collaboration pour l'apprentissage (dont les travaux de méta-analyses de Johnson et Johnson (1989) portant sur plus de 470 études) sans arriver à une définition facilement exploitable. Cependant, à travers un exercice systématique d'analyse compréhensive d'écrits, Bedwell et ses collègues (2012) proposent une définition de la collaboration, issue de l'intégration de plusieurs conceptualisations, qui nous semble bien refléter les réalités à l'université. Pour eux, la collaboration est un « processus évolutif par lequel deux ou plusieurs entités sociales participent activement et réciproquement à des activités conjointes visant à atteindre au moins un objectif commun » (p. 130). Ils complètent leur propos en illustrant les rapports entre la collaboration et trois termes courants (figure 1).

Le concept de travail en équipe partage avec la collaboration la plupart des éléments de leur définition. La collaboration est une manifestation du travail d'équipe et elle est un indice de la qualité du travail réalisé (Bedwell et al., 2012; Chiocchio, 2012). Leur principale différence réside dans leur niveau d'analyse : le travail en équipe implique exclusivement des individus au sein d'un groupe et ne peut par définition se faire entre groupes ou entre organisations. Ainsi, si tout travail en équipe est un exemple de collaboration, celle-ci peut exister sans celui-là. Concernant le terme coordination, il met en jeu les mécanismes et les interdépendances pour accomplir une tâche de manière efficiente à partir des ressources de l'équipe, mais là s'arrête leur point commun. Quant à la coopération, trop souvent considérée comme un synonyme de la collaboration, elle s'en distingue notamment par le fait qu'elle est une attitude ou une prédisposition à travailler avec d'autres personnes (Bedwell et al., 2012; Salas et al., 2007). Coopérer serait aussi davantage tourné vers la finalité, la production d'une œuvre sans tenir compte du processus, alors que la collaboration mise plutôt au processus en tenant moins compte du résultat. La coopération suppose une répartition des tâches bien définies et une mise en commun par juxtaposition des apports de chacun (Henri et Lundgren-Cayrol, 2001; Heutte, 2011). Pour Bedwell et ses collègues (2012), elle est nécessaire pour collaborer, mais elle ne décrit pas la collaboration en tant que telle. De leur côté, Chiocchio et ses collègues (2012), tout en relevant eux aussi les problèmes liés à la confusion des concepts de collaboration et de travail en équipe comme limitant notre compréhension de leur efficacité, proposent la définition de la collaboration que voici : « l'interaction des usages adaptés à une situation de quatre processus interdépendants : la communication en équipe, la synchronicité, la coordination explicite et la coordination implicite » (p. 12). La communication renvoie non seulement aux échanges d'informations entre les membres d'une équipe, mais aussi à un processus centré sur l'amélioration des interactions incluant notamment le partage libre des

idées, l'écoute et les rétroactions. La synchronicité est un processus dans lequel les membres effectuent leurs tâches à temps et dans le respect des autres tâches. La coordination explicite réfère au processus par lequel les membres échangent de l'information sur leurs rôles et leurs tâches, alors que la coordination implicite est celui où ils anticipent les besoins des autres et s'adaptent aux situations. Ces différents modèles théoriques de la collaboration en décrivent les étapes dynamiques. Ils mettent aussi l'accent sur l'efficacité, soit sur le jugement de l'équipe sur sa capacité à atteindre l'objectif commun (Chiocchio et al., 2012). L'efficacité est représentative de ce que font les coéquipiers, de leur perception sur la qualité de la performance (donc du fonctionnement de l'équipe, de ses mécanismes d'adaptations, des modes de prises de décisions, etc.) et de leur satisfaction des interactions. En somme, la collaboration est un concept multidimensionnel qui a été largement documenté et dont les ramifications théoriques, bien qu'elles soient nombreuses, comportent plusieurs points communs. Nous en abordons quelques-uns dans ce qui suit."

fig. 1



Les communautés de pratique sont des groupes de personnes qui se rassemblent afin de partager et d'apprendre les uns des autres, face à face ou virtuellement. Ils sont tenus ensemble par un intérêt commun dans un champ de savoir et sont conduits par un désir et un besoin de partager des problèmes, des expériences, des modèles, des outils et les meilleures pratiques. Les membres de la communauté approfondissent leurs connaissances en interagissant sur une base continue et à long terme, ils développent un ensemble de bonnes pratiques.

Une compétence est « un savoir-agir complexe prenant appui sur la mobilisation et la combinaison efficaces d'une variété de ressources internes et externes à l'intérieur d'une famille de situations ».

“Miller et al. (1996), définissent l’engagement cognitif à partir des niveaux de traitement de l’information dits en surface ou en profondeur. L’apprentissage en surface se définit par l’utilisation intentionnelle d’actions cognitives de base telles que l’apprentissage par cœur, la répétition, actions qui visent davantage la répétition mécanique que la compréhension significative des contenus à apprendre (Greene, 2015). L’apprentissage en surface est corrélé à des buts de performance qui visent à satisfaire aux exigences plutôt qu’à maîtriser la matière (Baeten et al., 2010). De son côté, l’apprentissage en profondeur est caractérisé par l’utilisation de fonctions cognitives complexes (Dinsmore & Alexander, 2012). Les modèles d’auto-régulation en recherche à ce jour attribuent trois caractéristiques aux habiletés d’auto-régulation : la métacognition, la motivation, la participation active à son processus d’apprentissage (Romainville, 2000 ; Zimmerman & Labuhn, 2012). Ces habiletés sont grandement influencées par les formes de rétroaction données à l’étudiant (Zimmerman & Labuhn, 2012). Les recherches ont montré que les habiletés d’auto-régulation développées par un étudiant favorisent l’engagement cognitif dans le contexte d’un cours, mais aussi dans le cadre de toutes ses études (Romainville, 2000 ; Zimmerman & Labuhn, 2012). Les étudiants ayant des buts futurs en lien avec leur apprentissage déploient des degrés d’attention et d’efforts supérieurs (Dweck & Leggett 1988 ; Greene, 2015). Frederick et McColskey (2012) considèrent également que la cohérence de la tâche perçue est tributaire du niveau d’engagement cognitif de l’étudiant et que celui-ci se manifeste par des efforts et une persévérance accrue dans l’exécution d’une tâche ou dans l’étude. Enfin, l’engagement situationnel est une dimension de l’engagement cognitif ajoutée lors de la traduction du questionnaire de Miller et al. (1996) par Leduc, Kozanitis & Lepage (2018). Elle vise à mesurer comment l’étudiant perçoit son engagement durant la tâche, comment il identifie ses efforts et sa persévérance lorsqu’il exécute la tâche et de quelle manière il se sent absorbé par la tâche (Leduc, Kozanitis & Lepage, 2018 ; Rotgans & Smith, 2011).”

“L’innovation est une activité délibérée qui tend à introduire de la nouveauté dans un contexte donné, et qu’elle est pédagogique parce qu’elle cherche à améliorer substantiellement les apprentissages des étudiants en situation d’interaction et d’interactivité. En contexte universitaire, les innovations pédagogiques sont souvent décrites comme tout ce qui ne relève pas de l’enseignement magistral, méthode encore utilisée par une très grande majorité de professeurs.”

Plus de 300 définitions ont été identifiées dans la littérature (Cros,1997), et chaque domaine se l'approprie en fonction de sa matrice disciplinaire (Astolfi, 2008). Cros définit l'innovation pédagogique comme « basée sur un nouveau relatif et contextualisé ; elle est changement selon une action finalisée qui s'inscrit dans un processus »(Cros, 1997, p. 48). Elle est dès lors perçue comme une forme de militantisme pédagogique pour répondre « à des difficultés concrètes ou à des vices du système que l'on refuse de tolérer » (Cros, 2004, p. 22). Plus généralement, elle peut naître de la controverse entre certains acteurs, entendue par l'entité supérieure pour transformer la situation (Durance, 2010 ; Durance et Mousli, 2010).

Selon Cros (2004), cinq éléments composent l'innovation pédagogique :

1. le « nouveau », affirmé comme tel par l'innovateur ;
2. le « produit », ce qui est donné pour la première fois aux apprenants ;
3. « le changement » avec une volonté consciente d'améliorer les pratiques ;
4. « une action finalisée » qui se construit sur des valeurs ;
5. le « processus » enfin, avec l'idée d'une zone d'inconfort qui ne permet pas de garantir un résultat (p. 17-21), mais qui permet de vivre une nouvelle « aventure » en prenant des risques (Cros, 2017, p. 38).

Plus récemment, Cros (2017, p. 39) pose comme « invariants » de l'innovation : la créativité, le nouveau, le changement et le processus. L'innovation est ainsi, à la fois, le résultat d'un produit destiné à favoriser les apprentissages des élèves, et le fruit d'un processus. Pour être innovant, l'individu passe par des processus créatifs (Capron Puozzo, 2016c ; Giglio, 2014). L'innovation pédagogique, reconnue comme telle, peut donc se traduire à plusieurs niveaux :

- 1) le corps enseignant (Cros, 2007),
- 2) le plan d'études/de formation,
- 3) l'institution scolaire ou de formation ou universitaire (Bédard et Béchard, 2009),
- 4) le curriculum (Bédard et Béchard, 2009et),
- 5) les politiques éducatives (Robinson, 2011).

Bédard et Raucent (2015) identifient trois enjeux fondamentaux de l'innovation pédagogique :

- 1) les conditions favorables et défavorables,
- 2) les tensions et
- 3) la pérennité de l'innovation.

Innover dans l'enseignement implique aussi de ne pas restreindre l'analyse du concept, d'un côté, à l'innovation curriculaire et, de l'autre, à l'innovation technologique et pédagogique (Cros, 2009). Au contraire, une vision plus décloisonnée d'un système holistique et écologique favorise la construction d'un esprit d'innovation au sein d'une institution adaptée et ancrée dans les besoins d'une société apprenante. Se pose ensuite la question tant redoutée de l'évaluation de cette innovation (Cros, 2004). La recherche porte alors sur cette variable transversale à ces différentes formes d'innovation, pour analyser, de manière qualitative ou quantitative, ce concept aussi bien en tant que processus (étapes du changement, remédiation effectuée, nombres d'idées engendrées, retenues et écartées, etc.) que comme produit final (une nouvelle formation en ligne, un nouveau curriculum, une nouvelle évaluation qualité, une nouvelle pédagogie, etc.).p.28-29

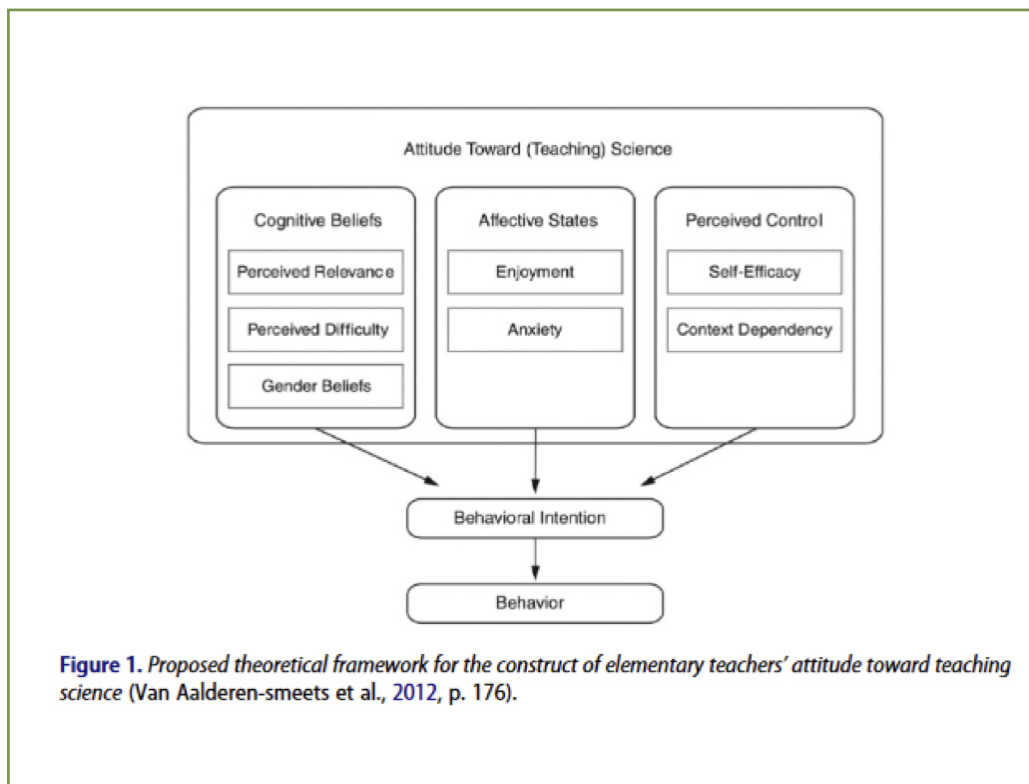
“Plusieurs conceptualisations de la motivation peuvent être citées telles que la théorie de l'autodétermination (Ryan et Deci, 2017), le paradigme social cognitif (Bandura, Lecomte et Carré, 2007) ou le modèle d'expectancy-value (Eccles et Wigfield, 2002). Le modèle de la dynamique motivationnelle de Viau (2009) constitue une excellente synthèse en français de ces travaux. D'autres synthèses peuvent également être citées telles que l'ouvrage de Galand et Bourgeois (2006).

Trois éléments constitueraient le type de motivation que l'étudiant pourra mettre en place lors d'une activité d'apprentissage : i) le sens qu'il peut attribuer à l'activité, ii) sa capacité à mener cette activité à bien, iii) la possibilité pour lui d'influer sur le déroulement de cette activité”

Le tutorat est ici vu comme un moyen d'apprentissage planifié dans lequel un apprenant plus compétent (le tuteur) veut soutenir un de ses pairs apprenant (le tutoré) dans l'acquisition ou le développement de connaissances et de compétences (Annoot, 2001; Papaïoannou et al., 2015; Topping et Ehly, 2001). Le tuteur peut aussi soutenir la motivation du tutoré et son intégration dans un milieu (Annoot, 2001; Désy, 1996). Le tutorat se veut bénéfique pour le tutoré comme pour le tuteur, qui sont tous les deux des apprenants pouvant bénéficier de leur relation sur les plans affectif, cognitif et métacognitif (Clark et Andrews, 2009; Gatti et Blary, 2017; Topping et Ehly, 2001). Les programmes de tutorat seraient surtout mis en place en milieu scolaire, même si certains dispositifs de formation en entreprise sont désignés comme du « tutorat » (Cohen-Scali, 2008; Fredy-Planchot, 2007). Par exemple, pour Fredy-Planchot (2007), le tutorat est une « situation de travail accompagnée » où un « professionnel confirmé » soutient une « personne novice » dans l'acquisition de compétences nécessaires à son travail tout en favorisant son intégration dans sa nouvelle fonction et dans l'entreprise. Cette façon de voir le tutorat se rapproche beaucoup de la définition que plusieurs auteurs font du mentorat, dont on parle plus fréquemment dans les milieux de travail ou dans d'autres organisations, notamment sportives, communautaires et criminelles (Barrette, 2017; Haggard et al., 2011; Ouellet et al., 2022; Perrier et al., 2015). Plusieurs auteurs relèvent cette confusion fréquente entre le tutorat et le mentorat (Clark et Andrews, 2009; Topping et Ehly, 2001). Pourtant, la relation de mentorat apparaît plus hiérarchique que celle de tutorat : le mentor est plus expérimenté et souvent plus âgé que le mentoré, qui bénéficie davantage de la relation (Clark et Language and Literacy Volume 24, Issue 3, 2022 Page 3 Andrews, 2009; Gagnon et Duchesne, 2018). De plus, si le tuteur cherche surtout à soutenir l'acquisition de connaissances et de compétences chez le tutoré, le soutien d'intégration est une clé du mentorat : le mentor aide le mentoré à trouver sa place dans l'organisation et peut lui donner accès à de nouvelles opportunités (Haggard et al., 2011; Ouellet et al., 2022).

Although definitions of attitude vary, authors agree that attitude is a complex construct involving three dimensions (Ajzen & Fishbein, 2005; Jones & Leagon, 2015; Venturini, 2007). In S&T education, the cognitive dimension includes beliefs and convictions about science as well as perceptions about the importance of science for oneself and for society; the affective dimension refers to the feelings about science and science teaching; and the behavioral dimension refers to behavior that consistently responds favorably or unfavorably to a given scientific object (Reid, 2006). Attitude is often measured as a single subcomponent such as beliefs and perceptions about science (Jones & Leagon, 2015; Tsai, 2002), self-efficacy (Bursal, 2012; Cantrell et al., 2003; Eshach, 2003; McKinnon & Lamberts, 2014; Riggs & Enochs, 1990), and pleasure (Kazempour, 2014; Zembylas, 2002). Measuring a single subcomponent does not account for the multidimensional nature of attitude and the dynamic interaction that exists between these subcomponents (Barmby et al., 2008; Van Aalderen-smeets et al., 2012). As part of their reflection on teachers' attitude toward science and teaching science, Van Aalderensmeets et al. (2012) proposed a new theoretical framework, largely inspired by the theory of planned behavior, which emphasizes the link between beliefs and behavior (Ajzen, 2002). Figure 1 illustrates their three-dimensional model, composed of cognitive beliefs, affective states, and perceived control.

fig. 1



Blended learning (BL) is situated on a continuum between face-to-face and online learning (Lakhali & Meyer, 2019). The Handbook of Blended Learning defined BL as a combination of face-to-face and online activities (Bonk & Graham, 2012), while some more precise definitions explicitly identify a decrease in face-to-face meetings (Bates, 2018; McGee & Reis, 2012; Picciano, 2009), e.g., between 30 and 79% of online learning (Allen & Seaman, 2016). Although this point is not necessarily made explicit in the literature, the present study considers that such a decrease should be inherent to BL so as to avoid a one-and-a-half course phenomenon (McGee & Reis, 2012). Given the aim of BL to combine the benefits of synchronous interactions with online flexibility and considering the improvements in digital technologies, new BL environments that allow synchronous activities to happen online instead of face-to-face for all or part of the students have also emerged in the last 15 years (Lakhali et al., 2017, 2020). The literature describes three common BL environments: 'Traditional' Blended, Blended Online, and Blended Synchronous courses (Lakhali & Bélisle, 2020; Lakhali et al., 2020; McGee & Reis, 2012). First, Traditional Blended Courses combine face-to-face with asynchronous online T&L activities. Second, Blended Online Courses combine synchronous and asynchronous online T&L activities (Power, 2008; Power & Vaughan, 2010). Also found in the online learning literature, they are part of BL since synchronous online meetings enable real-time interactions between students and teachers, as is the case for face-to-face meetings. Finally, Blended Synchronous Courses combine asynchronous online with synchronous face-to-face/online activities where on-campus/remote students simultaneously participate (Bower et al., 2015; Lakhali et al., 2017, 2020; Raes et al., 2019, 2020). In some cases, students may also have the possibility to watch meeting recordings or alternative videos instead of participating in synchronous T&L activities, thus being offered full flexibility of participation corresponding to HyFlex Courses (Beatty, 2007, 2014, 2019).

While there is no universal definition of blended learning, it is increasingly defined as the integration of online and traditional face-to-face class activities in a planned, pedagogically valuable manner with a portion of face-to-face time replaced by online activity (Dziuban et al., 2016, p.8)

Recognized as a complex and multifaceted construct, student engagement is rooted in action (Bond et al., 2020; Kahu, 2013; Reschly & Christenson, 2012). Here considered in a course context, it represents the investment and energy that students devote to learning (Borup et al., 2020; Fredricks et al., 2016; Skinner & Pitzer, 2012). Often described as a multidimensional psycho-social process, numerous authors (Bond et al., 2020; Christenson et al., 2012; Fredricks et al., 2019; Kahu, 2013; Lawson & Lawson, 2013; Manwaring et al., 2017; Schindler et al., 2017) refer to the definition provided by Fredricks et al. (2004) based on a qualitative literature review. These authors define student engagement as having three interrelated dimensions: behavioral, emotional, and cognitive. In a course, student behavioral engagement concerns their participation in activities and compliance with rules or norms. Next, student emotional engagement refers to their emotional reactions to activities, peers, and the teacher, and their sense of belonging to the course. Finally, student cognitive engagement corresponds to their psychological investment in activities to master complex knowledge, as well as their use of learning or metacognitive strategies. Christenson et al. (2012) summarize student engagement by stating that “engaged students do more than attend or perform academically; they also put forth effort, persist, self-regulate their behavior toward goals, challenge themselves to exceed, and enjoy challenges and learning”

“Engagement refers to a student’s active involvement in a learning activity (Christenson, Reschly, & Wylie, 2012). It functions as a student-initiated pathway to highly valued educational outcomes, such as academic progress and achievement (Jang, Kim, & Reeve, 2012; Ladd & Dinella, 2009; Skinner, Kindermann, Connell, & Wellborn, 2009; Skinner, Zimmer-Gembeck, & Connell, 1998). It is a multidimensional construct consisting of three distinct, yet intercorrelated and mutually supportive, pathways to academic progress—namely, its behavioral, emotional, and cognitive aspects (Christenson et al., 2012; Fredricks, Blumenfeld, & Paris, 2004; Skinner, Kindermann, Connell, & Wellborn, 2009). Behavioral engagement refers to how involved the student is in the learning activity in terms of attention, effort, and persistence; emotional involvement refers to the presence of positive emotions during task involvement such as interest and to the absence of negative emotions such as anxiety; and cognitive engagement refers to how strategically the student attempts to learn in terms of employing sophisticated rather than superficial learning strategies, such as using elaboration rather than memorization. This three dimensional portrayal of what actively involved students do is accurate, but it is also incomplete. Students do become behaviorally, emotionally, and cognitively involved in the learning activities their teachers provide (e.g., write an essay, solve a math problem), and their extent of effort, enjoyment, and strategic thinking does predict important outcomes, such as achievement. But students also do more than this. Students also, more or less, proactively contribute into the flow of instruction they receive as they attempt not only to learn but also to create a more motivationally supportive learning environment for themselves (Bandura, 2006).”

Reeve and Tseng (2011) initially proposed the concept of agentic engagement. They defined it as “students’ constructive contribution into the flow of the instruction they receive” (p. 258). To characterize students’ agentic engagement, these researchers offered classroom-based examples such as “offer input, express a preference, offer a suggestion or contribution, ask a question, communicate what they are thinking and needing, recommend a goal or objective to be pursued, communicate their level of interest, solicit resources or learning opportunities, seek ways to add personal relevance to the lesson, ask for a say in how problems are to be solved, seek clarification, generate options, communicate likes and dislikes, . . . ” (Reeve & Tseng, 2011, p. 258). These examples were extracted from extensive field notes in which trained raters used the Hit-Steer Observation System (Fiedler, 1975; Koenigs, Fiedler, & deCharms, 1977) to typify how students proactively attempt to learn and contribute into the flow of instruction their teachers provide. From this database and from the writings of motivation theorists who described what agentic students do— e.g., deCharms’s (1976) origins in the classroom, Bandura’s (1997) efficacious learners, and Ryan and Deci’s (2000) autonomously motivated students—Reeve and Tseng (2011) operationally defined the agentic engagement construct with the following five items: • During class, I ask questions. • I tell my teacher what I like and what I don’t like. • I let my teacher know what I’m interested in. • During class, I express my preferences and opinions. • I offer suggestions about how to make the class better. What these five acts of agentic engagement have in common is that each is a unilateral contribution into the flow of instruction. Communicating one’s preferences or asking a question, however, may or may not advance one’s learning or improve one’s learning conditions. What would be more likely to do so would be transactional (Sameroff, 2009) or dialectical (Reeve, Deci, & Ryan, 2004) classroom activity. With transactional activity, positive student outcomes are not a function of student activity (agentic engagement) but, rather, are the result of the unfolding of reciprocal processes between student and teacher. What students do (display engagement) affects and transforms what teachers do (provide instruction) and vice versa, and it is these emerging transactions that lead to greater or lesser positive student outcomes. With dialectical activity, student-initiated questions and communications affect change in and transform the teacher’s instructional behavior, just as the teacher’s instructional behavior in turn affects change in and transforms the quality and quantity of the student’s engagement. Hence, agentic engagement can be viewed not just as a student’s contributions into the flow of instruction but also as an ongoing series of dialectical transactions between student and teacher. How agentic students contribute transactionally and dialectically into the instructional flow is illustrated graphically in Figure 1. The four horizontal lines communicate that (a) student engagement emerges out of and publically expresses the quality of students’ underlying motivation and (b) students attain learning related outcomes in proportion to which they exert effort, experience enthusiasm, think strategically, and contribute constructively. What all four horizontal lines have in common is that they represent naturally occurring expressions of students’ underlying academic motivation that functionally translate students’ academic motivation into positive educational outcomes. Of particular importance is the addition of the fourth horizontal line to communicate that agentic engagement explains unique variance in students’ learning and achievement. The curved line in the lower portion of the figure

communicates a unique property of agentic engagement—namely, that, through their acts of agentic engagement, students—more or less—attempt to join forces with the provider of the learning environment (i.e., the teacher) to create for themselves a more motivationally supportive learning environment. These acts of agentic engagement are qualitatively distinct from the other three aspects of engagement in that they are intentional, proactive, and teacher-collaborative ways of engaging in learning activities. If these agentic contributions do transform how motivationally supportive the learning environment becomes (e.g., greater autonomy support, greater access to interesting and personally valued learning activities), then the learning environment becomes increasingly conducive to the types of student motivation (i.e., origin motivation, autonomous motivation, academic efficacy) capable of energizing, directing, and sustaining students’ classroom engagement.

fig. 1

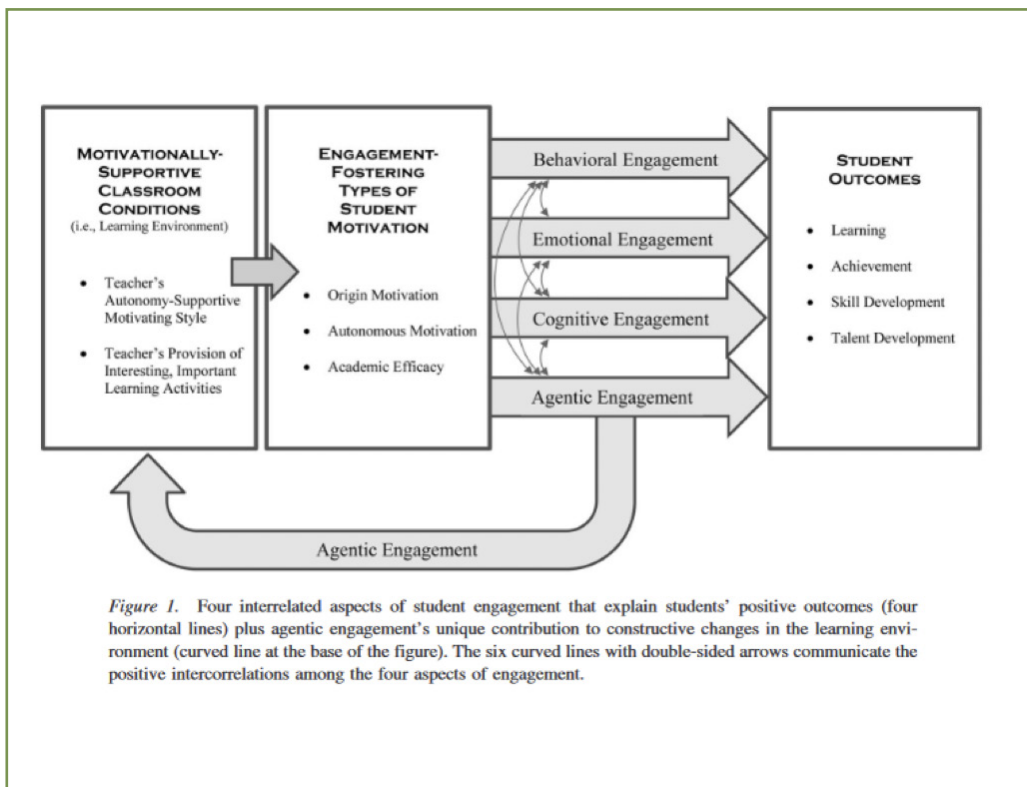


Figure 1. Four interrelated aspects of student engagement that explain students’ positive outcomes (four horizontal lines) plus agentic engagement’s unique contribution to constructive changes in the learning environment (curved line at the base of the figure). The six curved lines with double-sided arrows communicate the positive intercorrelations among the four aspects of engagement.

## Agentic Engagement as a New Educational Construct

Engagement represents the range of action students take to advance from not knowing, not understanding, not having skill, and not achieving to knowing, understanding, having skill, and achieving. It is what students do to make academic progress. To make progress in learning a foreign language, for instance, students can pay close attention to sources of information, invest effort, and persist in the face of setbacks, which is behavioral engagement. Or, they can enhance their curiosity and minimize their anxiety and frustration, which is emotional engagement. Or, students can apply sophisticated learning strategies and carry out mental simulations to diagnose and solve problems, which is cognitive engagement.

These are three empirically validated pathways to academic progress (Christenson et al., 2012). But agentic engagement is a fourth pathway. Proactively, students can contribute into the flow of instruction both to enhance their learning and to negotiate for the interpersonal support they need to energize their task-related motivation. To do so, they can express their preferences, ask questions, and let the teacher know what they need, want, and are interested in. The acknowledgment of this breadth of engagement activity expands the current three-aspect conceptualization of student engagement into a four-aspect conceptualization, as represented in Figure 1. Agentic engagement is similar to the other three aspects of engagement, as it too is a constructive student-initiated pathway to academic progress; but it is also meaningfully different. Conceptually, agentic engagement is a uniquely proactive and transactional type of engagement. Proactively, agenticallly engaged students take action before the learning activity begins (e.g., “Teacher, can we do x?”); transactionally, they negotiate for a more motivationally supportive learning environment (e.g., how challenging, personally relevant, need-satisfying, or goal congruent the learning activity is). The other three types of engagement largely take the teacher’s instruction as it is given, as students use their behavior, emotion, and cognition as ways of translating that teacher-provided instruction into student-acquired knowledge, understanding, and skill. Empirically, agentic engagement has been shown (a) to correlate only modestly with the other three aspects of engagement and (b) to explain unique variance in students’ positive outcomes that the other three aspects cannot explain (Reeve & Tseng, 2011). That is, agenticallly engaged students are taking achievement-fostering action that is something more than just their behavioral, emotional, and cognitive engagements. Agentic engagement is also meaningfully different from other proactive, collaborative, and constructive classroom events. For instance, formative assessments and personal response systems (“clickers”) are collaborative, constructive, and sometimes proactive approaches to instruction that facilitate learning, but they represent teacher-initiated, rather than student-initiated, action. A teacher’s instructional effort to design and implement a constructivist learning environment also fits within this category of teacher-initiated action (Brown & Campione, 1996). Instrumental (or “adaptive”) help-seeking is student-initiated and collaborative, but it is not necessarily either proactive or constructive (i.e., it generally does not correlate with student achievement; Pajares, Cheong, & Oberman, 2004). Self-regulated learning involves student-initiated, proactive, intentional, and constructive regulatory processes and actions (Zimmerman & Schunk, 2011), but existing theoretical frameworks do not yet incorporate the concept of agentic engagement into their conceptualization of how students actively involve themselves in learning activities (as will be elaborated on in the General Discussion). Agentic engagement is the classroom concept that best captures student-initiated, proactive, intentional, collaborative, and constructive action. Agentic engagement is not only a pathway to academic progress, but it is also

a student-initiated pathway to a more motivationally supportive learning environment. There is some evidence that students' behavioral engagement also pulls a more supportive style out of teachers and that students' behavioral disengagement pulls out a more conflictual or controlling style (Pelletier, SeguinLevesque, & Legault, 2002; Skinner & Belmont, 1993), although we can find no evidence that emotional or cognitive engagement pulls a more supportive style out of teachers. This behavioral engagement effect on teachers' motivating styles is, however, an indirect or inadvertent (albeit fortuitous) effect. In their reasoning as to why teachers respond to students' behavioral engagement, Skinner and Belmont (1993) argued that teachers find students' behavioral disengagement to be aversive and that this leads teachers to feel incompetent or unliked by their students. As a result, teachers tend to offer less support to these students. Behavioral disengagement also signals poor student motivation, and teachers sometimes seek to remediate such low motivation by applying pressure and coercion to motivate the unmotivated. Thus, behaviorally engaged students may not intentionally recruit their teachers' autonomy support any more than behaviorally disengaged students intentionally recruit teachers' control and coercion. In contrast, agentic engagement is intentional, purposive student initiated action to render the learning environment to become more motivationally supportive.

What we usually view as a simple notion, the body, opens to a multitude of theoretical perspectives that build on different traditions and premises about science learning (e.g. Amin et al., 2015; Euler et al., 2019; Hardahl et al., 2019; Kersting & Steier, 2018; Niebert et al., 2012).

Often, science education researchers use relevant concepts of embodiment and embodied cognition interchangeably or do not address the complexity of these concepts at all. The terms “embodiment” and “embodied cognition” are used differently within different perspectives and traditions. While we refine possible meanings of these terms below, broadly, we understand “embodiment” as being concerned with the experiences that arise from having living bodies in our interactions with the material and sociocultural world.

Embodiment is a fundamental aspect of lived experience, and the study of embodiment builds on the basic view that “our knowledge of the world is inseparable from our experiences of the bodies that we are” (Popova & Raczaszek-Leonardi, 2020, p. 3). We use the term “embodied cognition” broadly to refer to the processes of thinking, knowing and communicating that rely in some way on embodiment. Embodied cognition describes cognitive processes that deeply rely on features of the physical body beyond the brain (Wilson & Foglia, 2017). As a loosely knit family of research programmes, the study of embodied cognition builds on the assumption that we can improve our understanding of the mind by characterising the role of the body in cognition (Wilson & Foglia, 2017).

What we usually view as a simple notion, the body, opens to a multitude of theoretical perspectives that build on different traditions and premises about science learning (e.g. Amin et al., 2015; Euler et al., 2019; Hardahl et al., 2019; Kersting & Steier, 2018; Niebert et al., 2012). Often, science education researchers use relevant concepts of embodiment and embodied cognition interchangeably or do not address the complexity of these concepts at all. The terms “embodiment” and “embodied cognition” are used differently within different perspectives and traditions. While we refine possible meanings of these terms below, broadly, we understand “embodiment” as being concerned with the experiences that arise from having living bodies in our interactions with the material and sociocultural world. Embodiment is a fundamental aspect of lived experience, and the study of embodiment builds on the basic view that “our knowledge of the world is inseparable from our experiences of the bodies that we are” (Popova & Raczaszek-Leonardi, 2020, p. 3). We use the term “embodied cognition” broadly to refer to the processes of thinking, knowing and communicating that rely in some way on embodiment. Embodied cognition describes cognitive processes that deeply rely on features of the physical body beyond the brain (Wilson & Foglia, 2017). As a loosely knit family of research programmes, the study of embodied cognition builds on the assumption that we can improve our understanding of the mind by characterising the role of the body in cognition<sup>1</sup> (Wilson & Foglia, 2017).

The flipped classroom was first used by Lage et al. (2000) and later popularized as an active teaching method by Bergmann and Sams (2012). Both research studies considered that inverting or flipping the classroom implies the acceptance that many of the activities that were normally developed previously inside the classroom now occur outside it, and vice versa. The definition provided by Bergmann and Sams (2012) has been the basis of the most recent flipped classroom literature. It defines this method in general terms as an approach in which the place where the different tasks are performed changes so that students watch the lectures on their own time outside the classroom. Instead, in the classroom, they perform the activities that have traditionally been considered homework, focusing on the parts of the material causing them difficulty (Hung, 2015; O'Flaherty & Phillips, 2015; He, Holton, Farkas, & Warschauer, 2016). As highlighted by Hung (2015), the students' preparation before the class is very important for them to be able to become more involved and to achieve more rewarding results.

The concept of interest is used in a variety of research fields, including psychology, educational psychology, sociology, S&T education (Krapp & Prenzel, 2011). Our study is located primarily in this last field. Our focus is to understand phenomena related to S&T education rather than to make a contribution to theorization about the concept of interest per se. The conceptual framework will therefore present the way we use the concept of interest to determine, based on writings in this field, the main dimensions (components) and indicators to use in order to develop tools for data collection and analysis. As Renninger & Hidi (2011) underscore, "The construction of a theoretically satisfactory interest measure requires a specification of the interest construct or a particular aspect of this construct that is used as a basis for operationalization" (p. 36). The synthesis published by these authors (Renninger & Hidi, 2011) clearly shows that there is no one stabilized and fully agreed-upon theoretical orientation towards the concept of interest. However, "general agreement can be found with regard to the central characteristics of the interest construct" (Krapp & Prenzel, 2011, p. 30). Three sets of characteristics can be found in most texts and will be used as a basis here to operationalize the concept in our research: a) the attributes of the concept of interest; b) the dimensions that make up this construct; and c) the analytical levels on which it is examined in studies.

#### Characterization of the concept of interest.

Following on Gardner (1996, in Krapp, 2007), many authors (Hidi, Renninger & Krapp, 2004; Krapp, 2007; Krapp & Prenzel, 2011; Renninger & Hidi, 2011) consider that "the decisive criterion of the interest construct which enables it to be clearly distinguished from several neighbouring motivational concepts [such as attitude and motivation] is its content specificity" (Krapp & Prenzel, 2011, p. 30). "One cannot simply have an interest: one must be interested in something" (Gardner, 1996, p. 6, in Krapp, 2007). "The interest construct is conceptualized as a relational concept: an interest represents or describes a more or less enduring specific relationship between a person and an object in his or her life-space" (Krapp, 2007, p. 8). The object of interest in the field of S&T can be a specific subject (biology, physics, chemistry, etc.), a specific area or field of knowledge (the study of animals), a concrete operation or object (lab manipulations), an abstract scientific activity (formulating a scientific problem or question, or analyzing data), etc. (Häussler, 1987; Häussler & Hofmann, 2000; Krapp, 2007; Krapp & Prenzel, 2011). When discussing S&T as an object of interest, it is also important to distinguish the way S&T are perceived in society (outside school) from the way it is taught and learned in school context. The focus of our research is the latter.

#### Dimensions of the concept of interest

While some researchers have characterized interest as an 'affective variable' or stressed this particular aspect in their studies (Rennie & Punch, 1991; Steinkamp & Maehr, 1983), others believe in the importance of not simply equating it with 'enjoyment while learning' (Krapp & Prenzel, 2011). Interest is a multidimensional construct whose operational definition requires emotional, cognitive (knowledge) and related value [value attributed to the object of interest] dimensions (Hidi, 2006; Hidi & Renninger 2006; Hidi, Renninger, & Krapp, 2004; Krapp, 2007; Krapp

&Prenzel, 2011; Renninger & Hidi, 2002, 2011; Schiefele, 2009).

Models such as the 'four-phase model' of interest development by Hidi & Renninger (2006) propose interdependency between these dimensions as interest grows and is maintained. Although the very earliest phases of interest might be considered to be an emotion and to involve minimal knowledge requirements (Hidi, 2006; Reeve, Jang, Hardre & Omura, 2002), "Hidi and Renninger suggested that for interest to develop, knowledge and value, in addition to affect, need to be present" (Ainley et Ainley, 2011, p. 69).

a) Emotional (affective) characteristics – According to the authors cited above, this "feeling-related" dimension refers to emotion and the sense of enjoyment provided by the actual or evoked presence of a given object, as well as the involvement in an interaction with it. For example, this can mean enjoying science, having fun with science or with its specific objects (contents, teaching methods, etc.). As Krapp (2007) recalls, "it has been proposed that emotional experiences are considered as related to the basic needs of competence, autonomy and social relatedness in order to characterise interest-specific emotional experiences" (p. 11).

b) Cognitive aspects – This dimension bears on object-related knowledge: what students know or think they know about it. Indeed, without knowledge, there is no interest. Students cannot be hoped to express interest in the inquiry process or in biology knowledge (such as photosynthesis), for example, without having some minimal knowledge of these objects. Moreover, interest in an object prompts a desire to find out more about it. Krapp (2007) noted that: A person who is interested in a certain subject area is not content with his or her current level of knowledge or abilities in that interest domain. Rather, there is a high readiness to acquire new information, to assume new knowledge and to enlarge the competencies related to this domain. But there is also a high readiness for activating interest-related competencies in situations that do not require new learning (p. 10).

c) Value-related characteristics – Ainley & Ainley (2011) "used data from the PISA international study of science achievement to suggest that value is a strong predictor of students' enjoyment of science and that enjoyment mediates the predictive effects of value in learning science" (Renninger & Hidi, 2011, p. 171). In our case, this is the value individuals attribute to the object of their interest (S&T or its components). According to Krapp (2007), From such a theoretical perspective, positive evaluation results from the degree of identification with the object of interest. The value component of an interest is also referred to by using the concept of 'self-intentionality' to make it clear that the goals and volitionally realised intentions related to the object area of an interest are compatible with the attitudes, expectations, values and other aspects of the person's self-system (p. 11). In connection with this dimension, one might also consider the role individuals ascribe to the S&T learned at school in their lives outside school. In our research, we suggest that while this value can be studied in a "specific" way (value attributed to S&T or to one of its characteristic objects), it can also be studied in a "relative" way via comparison of the value assigned to S&T with respect to the other school subjects (languages, arts, social sciences, etc.). Research into students' preferences for school subjects (Colley & Comber, 2003; Hendley, Stables, & Stables, 1996) shows the importance of taking relativity into account in connection with interest. Works stemming from the Sociology of Curriculum (Bernstein, 1971; 1997; Young, 1971, 1997) also show that the hierarchy of school subjects, widespread in school systems, has a strong impact on which subjects teachers and, consequently, students (Lenoir & Hasni, 2010)

will consider important or not to the school education. Students' interest and engagement in S&T is likely to also depend on this "relative value."

### Levels for studying interest

Numerous authors make a distinction between two levels of interest, which some consider to be two current directions of research in this area (e.g., Ainley et al., 2002; Hidi, 2001; Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006; Krapp, 2007; Renninger & Hidi, 2011; Schiefele et al., 1992; Swarat, Ortony, & Shieh, 2012): situational interest and individual (personal) interest.

a) Situational interest is characterized by its association with an external factor (a situation, a task, a context, etc.) to which an individual is exposed and in which the individual is involved in an interaction (Ainley et al., 2002; Hidi & Renninger, 2006).

The situation may produce a positive feeling (for example, the joy of engaging in a scientific experiment) or a negative one (for example, disgust in observing and describing the parts of a scorpion) (Swarat, Ortony, & Revelle, 2012). In the school context, this situation may involve, for example, specific knowledge to which students are exposed or the tasks in which they are involved (conducting experiments, listening to the teacher, reading textbooks, etc.). According to Hidi (2001, 2006) "this psychological state involves focused attention, increased cognitive functioning, persistence, and affective involvement" (Krapp, 2007, p. 9). Another characteristic of this type of interest is that even if it is transitory, under some conditions it can provide the basis for longer situational interest (Krapp, 2007): "When situational interest is maintained over time, or when it occurs repeatedly in response to the same stimuli, does it possibly lead to long-term interest, increased knowledge, changes in values, and consistent positive feelings" (Swarat et al., 2012, p. 4). In an extensive review, Hidi & Harackiewicz (2000) conclude that "situational interest can contribute to the development of long-lasting personal interest" (p. 155). In other words, certain conditions in the learning environment can do more than momentarily catch one's interest, they can also hold it (Hidi & Harackiewicz, 2000). When situational interest is sustained (held) by conditions in the learning environment, it may lead to intrinsic motivation and individual interest (Hidi & Harackiewicz, 2000).

b) Personal (individual) interest, a particular focus of this study, is characterized by the intrinsic desire to understand a specific topic that persists over time (relatively stable) (Krapp, 2007; Renninger & Hidi, 2011; Schraw & Lehman, 2001; Wade, 2001). It is a cognitive and affective quality that individuals carry with them from place to place. "The basis of personal interest appears to be pre-existing knowledge, personal experiences and emotions, high value" (Schraw & Lehman, 2001, p. 28). It develops slowly over time and tends to be long lasting (Schraw & Lehman, 2001). Over time, individual interest may be integrated into the person's value system and become one of its basic components.

Therefore, it is suggested that people carry with them a set of individual interests, which influence how they interact with various objects. When people with certain individual interest encounter a situation that matches the particular interest, their individual interest is actualized — referred to as actualized individual interest by some researchers (Swarat et al., 2012, p. 4).

Individual interest is based on existing knowledge about and values concerning tasks, objects, or ideas and is the desire to be involved in

activities related to these concepts (Swarat et al., 2012). This type of interest is personal, broad, and often long-lasting. Hidi & Harackiewicz (2000) describe individual interest in greater detail, stating that it is “a relatively stable motivational orientation or personal disposition that develops over time in relation to a particular topic or domain and is associated with increased knowledge, value and positive feelings” (p. 152).

c) Predisposition or intention to act. Another important characteristic of individual interest is that it leads to “a relatively enduring preference for certain topics, subject areas, or activities” (Schiefele et al., 1992, p.152) or to an “enduring predisposition to attend to certain objects and events and to engage in certain activities, contents or objects” (Hidi & Renninger, 2006, p.113). This behaviour or predisposition “is associated with a psychological state of positive affect and persistence and tends to result in increased learning” (Ainley et al., 2002, p. 545). The predisposition to act is understood here as a favorable response to a given object on a consistent basis. As regards the research on interest (Ainley & Ainley, 2011), We can predict that having a coherent body of science knowledge and understanding (knowledge), enjoying science (affect), and valuing science (value) will be predictive of the level of general interest in learning science (individual interest), which in turn will predict being currently engaged in science activities and having the intention to engage with science activities in the future (current and future engagements) (p. 55). In the context of our study, we consider that this predisposition to act can be examined at different levels, including a) the engagement in S&T classes and b) the intention to pursue S&T-related studies or careers.

“The general construct of interest refers to the psychological state of a person while engaging with some type of content” (Renninger and Hidi 2016, p. 8). In the research literature, the main references supporting the use of the interest construct [are] to Krapp and Hidi’s work, which insist on the ‘relationship (generally positive) between individuals and objects’” (p. 94). Interest is thus always in something and this something is usually indicated in the items used to assess it, such as disciplines, objects, or specific situations. Like the construct of attitude, interest is often considered to be composed of affective, cognitive, and behavioral dimensions.

An additional value component is frequently added when assessing it (with agreement items such as science is something important). The most popular model of interest is the four-phase model (Hidi and Renninger 2006). While the initial phases of the development of interest are considered as context- or situation- dependent (situational interest) and therefore more volatile, the last ones have been described as more resilient traits (individual interest).

The model suggests that repeated situationally interesting events can eventually increase the likelihood of developing an enduring and resilient individual interest. Since our research focuses on longitudinal evolution of perceptions and less on small-grain events, we will thus focus on the construct of individual interest. And since the educational focus of this research, the considered objects of interest will be science and technology as they are experienced by students in school, with agreement items like BI look forward to the next S&T lesson.

Though it could reasonably be hypothesized that interest can be found at the root of learning (like many correlational studies suggest (Singh et al. 2002)), researchers using cross-lagged panel designs have (surprisingly) often found no convincing causal relation between interest (or intrinsic motivation) and achievement (Marsh et al. 2005; Weidinger et al. 2017). Leibham et al. (2013) for example, found no evidence that early science interests (even in preschool) predicted later science achievement in 8-year-old boys, although it moderately predicted achievement in girls (Leibham et al. 2013). Some exceptions however do exist. Indeed, it was elsewhere found that math performance predicted later interest, but interest did not predict later performance (Ganley and Lubienski 2016, p. 189). Still, Ganley notes that the current literature provides inconsistent evidence for this relation” (2016, p. 184).

Of course, interest is also easily considered a precursor to the intention to pursue studies and a career in S&T (Taskinen et al. 2013). In fact, most scientists and engineers say that they became interested in science at an early age (Maltese and Tai 2010). However, we believe that the reverse hypothesis is often overlooked, especially with younger students. Indeed, young-sters’ intentions to pursue science may not always be motivated purely by interest. For instance, they might have family members in scientific professions, hold assumptions about the superiority of careers in S&T, be subjected to peer pressure, or simply have a positive or even exaggerated perception of scientists and of what they can do (e.g., superheroes, such as Iron Man and the Hulk, are often scientists). It is thus conceivable that, before being progressively introduced to more rigorous S&T, students might express interest for

reasons that are in fact external to S&T. And it is not unreasonable to think that these intentions could be causal and resilient forces that influence their perception set. Therefore, the potentially reciprocal relationship between intentions to pursue and other perceptual constructs might be worth monitoring during these crucial years.”

Interest is not an either-or proposition; rather, many scholars see interest as developmental. According to Hidi and Renninger's (2006) four-phase model of interest development, situational interest is triggered and maintained in the first two phases, and individual interest emerges and is maintained in the latter two phases. Additionally, each of the four phases has an affective (i.e. positive emotions accompanying engagement) and cognitive component (i.e. perceptual and representational activities related to engagement) of interest. Science interest can be conceptualised and measured at multiple levels of abstraction, either in a general sense (e.g. interest in science as a school subject) or by describing specific science topics in which a person might be interested (Häussler & Hoffmann, 2000). Situational interest in science is further recognised as a multidimensional construct that distinguishes between topical interest, interest in the context in which a topic is presented, and interest in an activity used to engage a student with a given topic (Bathgate et al., 2014). By assessing situational interest as a multidimensional construct, educators can adapt curriculum content (i.e. topics) to students' context and activity interests to either trigger or maintain student's situational interest (cf. Häussler & Hoffmann, 2000). While scholars debate whether topic, context, or activity is the main driver of interest (Bathgate et al., 2014; Jördens & Hammann, 2021), topics and activities have been found to reciprocally influence each other, with topic interest also being dependent on the context in which it is presented (Hammann et al., 2020; Häussler et al., 1998). Studies show that context interest can even support topic interest across scientific domains (Crouch et al., 2018; Renninger & Hidi, 2020). Student interest in science is well known to impact learning, quality of work, and academic persistence (Renninger & Hidi, 2020). Further, developing student interest can enhance academic success and influence future academic choices and career paths (Maltese & Tai, 2010; Potvin & Hasni, 2014; Patall & Hooper, 2019). Students' interest in and positive attitudes towards science have been found to be largely gender neutral in fourth-grade, with girls and boys expressing similar levels of interest (Jones et al., 2000; Riegle-Crumb et al., 2011). However, interest in science generally decreases as students progress from primary to high school, with the decline being more pronounced for girls than boys (Anderhag et al., 2016). Lower interest may be further associated with minimal exposure to and experiences with science during elementary school (Tytler et al., 2008; DeJarnette, 2012). However, even when students have little or no initial interest, cultivating their interest is still possible (see discussion in Renninger & Hidi, 2016). Importantly, students who have developed an interest in science at the primary level are less likely to quickly lose interest as they progress through school (Potvin & Hasni, 2014), with those who become interested in science by age eight being more likely to retain their interest in STEM as they transition into secondary school (Aschbacher et al., 2014). Therefore, fourth-graders are an ideal target audience for the Science Is Fun program, as they are likely to be receptive to and to benefit from early STEM intervention. Affective situational interest is the most applicable phase of interest development in the Science Is Fun program, where the primary aim is to expose students to the excitement of discovery and increase enjoyment of science. Science demonstration-experiments are an ideal approach for inciting triggered situational interest, as this phase of interest development is based on short-term changes in affective and cognitive processing, sparked by the environment (the exciting demonstrations) and usually supported externally rather than internally (Hidi & Renninger, 2006). Research demonstrates that hands-on interactions

in science activities can increase student interest levels (Holstermann et al., 2010), in particular for situational interest (Lin et al., 2013; Palmer et al., 2016), and that this effect is due to the student's success with, and novelty and relevance of the hands-on activity. The discrepant event aspect of the demonstration-experiment model has also been proposed as a stimulator of situational interest (Kang et al., 2012) as such events intrinsically motivate students to discover why their ideas may be inconsistent with their observations. The Science Is Fun model also supports interest by contextualising the science demonstrations through relevant, everyday experiences. Hoffmann (2002) found that contextualising energy science topics in everyday experiences was a contributing factor in increasing students' interest and motivation in learning physics. Further, intentionally contextualising teaching approaches have been found to be beneficial to students' learning with stronger effects for affective outcomes (Bennett et al., 2007; Krapp & Prenzel, 2011; Potvin & Hasni, 2014). Research by Watermeyer (2013) also supported that informal science demonstrations that utilise contextually familiar narratives can help to confirm the relevance of science to an audience and serve to motivate non-expert science learners. Sadler (2004) found that prior experiences of young audiences can differentially impact the interest of a demonstration. Based on this, Walker (2012) suggests that a variety of contextualizations are needed to appeal broadly to elementary learners.

As described by Cox, a faculty learning community is “a cross-disciplinary faculty and staff group of six to fifteen members (eight to twelve members is the recommended size) who engage in an active, collaborative, yearlong program with a curriculum about enhancing teaching and learning and with frequent seminars and activities that provide learning, development, the scholarship of teaching, and community building.” p.8

Mathematics anxiety is defined as feelings of tension and discomfort that might prevent someone from carrying out his or her actual capability in mathematical problems (Ashcraft, 2002) and can lead to the development of negative attitudes toward mathematics (Tooke & Leonard, 1998). These negative attitudes can prevent students from reaching their potential in terms of mathematical capability (Hannula, 2005). Pajares (1997) indicated that when people experience negative thoughts and fears about their capabilities, these negative affective reactions can further lower perceptions of that capability and result in stress, thereby potentially exacerbating poor performance and fear. The results of those studies underlining the negative effect of mathematics anxiety on mathematics achievement (e.g., Alexander & Cobb, 1984; Hackett, 1985; Hamid, Shahrill, Matzin, Mahalle, & Mundia, 2013; Jain & Dowson, 2009; Karakolidis, Pitsia, & Emvalotis, 2016; Lee, 2009; Lee & Stankov, 2013; Pitsia et al., 2017) agree that anxiety is a crucial barrier to teaching mathematics and equipping students with problem-solving skills. Sociocognitive theory suggests that individuals who do not perceive themselves to be capable of coping with threats become stressed and experience anxiety in similar or comparable circumstances (Bandura, 1977). Consequently, their functional levels become limited. Under the exact opposite circumstances as highlighted by Bandura (1989) and Lent, Lopez, Brown, and Gore (1996) the anxiety level is diminished and the individual experiences strong self-efficacy beliefs.

Metacognition, which is a significant predictor of general achievement and especially mathematics performance (Desoete & Veenman, 2006), can be defined as being aware of one's cognitive process and managing it when necessary (Flavell, 1976). Metacognition is considered in terms of two parts: metacognitive knowledge and metacognitive experiences (Efklides, 2008; Flavell, 1981). Metacognitive knowledge includes knowledge of oneself, the task at hand, and the strategy for successfully completing the required task (Flavell, 1979, 1987). Metacognitive experience is "what a person is aware of and what she or he feels when coming across a task and processing the information related to it" (Efklides, 2008, p. 279). Metacognitive experiences provide feedback to the behavioral control process by monitoring the implemented strategy, determining whether it is being successful, and assessing the outcomes (Moores, Chang, & Smith, 2006). When students are engaged in challenging tasks like mathematical problem solving, metacognition becomes more important (Holton & Clarke, 2015). Studies report that there is a high relationship between metacognitive skills and problem-solving skills (e.g., Jaafar & Ayub, 2010; Ozsoy, 2011). Metacognition has a complicated relationship not only with performance, but also with behavior, in that it triggers the problem-solving behavior, monitors performance, and changes behavior if things are not going as expected. There is a strong positive relationship between self-efficacy and metacognition (Cera, Mancini, & Antonietti, 2013; Hoffman & Spatariu, 2008), both of which are closely related to mathematics performance and share certain properties (Moores et al., 2006).

“Flavell (1979), the founder of research on meta-cognition, defines meta-cognition as Bthinking about thinking”. He distinguishes between two components of metacognition: (a) knowledge of cognitive processes and products; and (b) ability to control, monitor, and evaluate cognitive processes. Flavell (1979) argues that knowledge of cognition depends on the following inter-related components: metacognitive knowledge about self, the task and strategies; knowledge about how to use the strategies; and meta-cognitive experience. The later refers to one’s feeling about being successful (or unsuccessful) in performing the task. According to this model, the meta-cognitive knowledge leads to strategy use which in turns affects the meta-cognitive experience that affects the acquisition of meta-cognitive knowledge and so on. From the 1990s on, much of the research on meta-cognition has focused on its structure and specific components. For example, Schraw and Dennison (1994) describe eight meta-cognitive scales, classified into two factors: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to declarative (the Fwhat\_), procedural (the Fhow\_), and conditional (the Fwhen\_ and Fwhy\_) knowledge. Regulation of cognition refers to planning, monitoring, debugging, evaluating, and information managing. (The BMeasurement^ section describes the operational definitions of the scales). While many studies analyzed meta-cognition independently on the domain in which the cognitive and meta-cognitive processes are activated, Kramarski and Mevarech (2003) suggest distinguishing between general and domain-specific metacognitive knowledge. They argue that the distinction between general and domain specific meta-cognitive processes is similar to the distinction made between general and domain-specific cognitive processes. According to Kramarski and Mevarech (2003) Bgeneral meta-cognitive knowledge is knowing about and being able to control and regulate problem solving processes regardless of the specific domain from which problems or tasks are drawn. Domain-specific meta-cognitive knowledge focuses on the unique features of each domain and therefore varies among domains” (p. 284).

“Motivation, which is a tendency to behave in a specific direction, has two main dimensions: intrinsic and extrinsic. Extrinsically motivated students seek out external rewards for their behavior in the shape of high grades, academic honors, scores on tests, and awards from parents or teachers. Intrinsically motivated students engage in learning activities to satisfy their interest or curiosity. This type of motivation reflects students’ intrinsic interest in the content, materials, or task. Extrinsically motivated students also engage in learning to satisfy their needs, but their needs are for something different. Studies that investigate motivation’s association with negative or positive impacts on mathematical problem solving (Alcı, Erden, & Baykal, 2008; Ozcan, 2016) report that individuals with enough intrinsic motivation are not affected by negative external factors before the learning takes place. In the research literature, motivation and self-efficacy are regarded as nested constructs (Zimmerman, 2008) and self-efficacy is seen as a motivational measure in conjunction with internal and external motivational measures (Vollmeyer & Rheinberg, 1999). Higher self-efficacy expectations can lead to an increase in motivation (Bandura, 1986; Braten et al., 2004; Liu & Koirala, 2009).”

Project-based learning (PjBL) refers to an inquiry-based instructional method that engages learners in knowledge construction by having them accomplish meaningful projects and develop real-world products (Brundiers & Wiek, 2013 ; Krajcik & Shin, 2014). Krajcik and Shin (2014) indicated six hallmarks of PjBL, including a driving question, the focus on learning goals, participation in educational activities, collaboration among students, the use of scaffolding technologies, and the creation of tangible artifacts. Among all these features the creation of artifacts that solve authentic problems is most crucial, which distinguishes PjBL, from other student-centered pedagogies, for example, problem-based learning (Blumenfeld et al., 1991 ; Helle, Tynjälä, & Olkinuora, 2006). This creation process requires learners to work together to find solutions to authentic problems in the process of knowledge integration, application, and construction. Instructors and community members (e.g. clients), normally as facilitators, provide feedback and support for learners to assist their learning process.

“Self-efficacy, defined as a judgement or assessment of one’s capabilities to successfully perform a particular given task (Bandura, 1977, 1997), has been highlighted as an important predictor of academic performance in general (Braten, Samuelstuen, & Stromso, 2004; Ferla, Valcke, & Cai, 2009; Liu & Koirala, 2009) and of mathematics achievement specifically (Ferla, Valcke & Cai, 2009; Pajares & Graham, 1999; Pajares & Miller, 1995). Self-efficacy is thought to influence behavior through motivational, cognitive, and affective processes. In the research literature, self-efficacy and self-concept have been presented as being interrelated. Mathematics self-concept reflects more general beliefs about competence (i.e., “I’m good at mathematics”) whereas, mathematics self-efficacy refers to much more specific and situational judgments of capabilities (i.e. “I’m confident I can solve this type of two-digit subtraction problem”) (Linnenbrink & Pintrich, 2003). Although it is difficult to find empirical evidence for the existence of obvious differences between these two constructs, some research (Bong & Skaalvik, 2003; Ferla et al., 2009; Lee, 2009) has highlighted the importance of self-efficacy on mathematics performance. Students with higher mathematics self-efficacy feel confident about being able to cope with difficult mathematical problems and are more accurate in mathematical computations (Collins, 1982; Hoffman & Schraw, 2009). Students with high mathematics self-efficacy levels were more resilient and patient in the face of adversity, invested more effort and time in order to achieve, and participated more effectively in class (Pajares, 2002). Previous research has reported that mathematics self-efficacy is positively related to mathematical problem solving (Kramarski, 2004; Kramarski, Mevarech, & Arami, 2002) and mathematics performance (Hoffman & Spatariu, 2008; Kabiri & Kiamanesh, 2004; Liu & Koirala, 2009; Pajares & Graham, 1999). Pajares and Miller (1995) pointed out that mathematics self-efficacy was a stronger predictor of success in solving specific mathematical problems than of total mathematics performance.”

'Self-efficacy refers to people's beliefs in their capabilities to produce given attainments and it has been shown to be a powerful predictor of one's willingness to engage and be successful in different areas of life (Bandura, 1994)'

'Developed by Bandura (1977), self-efficacy is defined as a subject's belief in their ability to perform a task of a scientific nature according to their knowledge and skills (Riggs & Enochs, 1990).'

Self-efficacy is defined as a belief about one's ability to succeed in a particular situation or perform a behavior, e.g. conduct a science experiment, discover the solution to a problem (Bandura, 1977; Maddux, Sherer, & Rogers, 1982; Robnett et al., 2015). Science self-efficacy has been found to predict student academic achievement in K-12 STEM learning contexts (Britner & Pajares, 2001, 2006) and increase task value, the effort to succeed in a task at hand (Doménech-Betoret et al., 2017). Together, high self-efficacy and high science achievement have been found to be strongly associated with students' decisions to pursue science-related majors and careers (Aurah, 2017; Britner & Pajares, 2006; Chachashvili-Bolotin et al., 2016). Students with high self-efficacy can recover quickly from setbacks, while students with low self-efficacy are less likely to persevere and may find themselves trapped in a self-fulfilling prophecy when faced with academic challenges (Margolis & McCabe, 2006). Potvin and Hasni's (2014) systematic review of the literature on K-12 students' connection to science and technology identified positive relationships between self-efficacy for science and science interest and motivation (See also, Chan, 2022). Moreover, researchers have posited a lack of science self-efficacy by both boys and girls (Sezgintürk & Sungur, 2020) as a reason for the high proportion of K-12 students' self-reported lack of interest in pursuing STEM careers (Ballen et al., 2017; Blotnick et al., 2018). One way to raise elementary students' science self-efficacy is by observing others like themselves doing science (Jones et al., 2021). According to Bandura (1997), one vehicle for increasing self-efficacy is vicarious experiences whereby an individual's self-efficacy is directly impacted by the similarity they perceive between themselves and a credible model they observe to effectively perform a task. Vicarious experience works by providing individuals with information about their own perceived capabilities as they compare themselves to others doing science and are an additional source of self-efficacy beliefs (Britner & Pajares, 2006). Therefore, exposure to same-race, same-gender role models can positively influence science self-efficacy in girls and ethnic and racial groups minoritized in STEM through seeing or visualising people similar to themselves performing successfully, reinforcing that they themselves are similarly capable (e.g. Clarke-Midura et al., 2018; Todd & Zvoch, 2018). Women and individuals from other minoritized populations are already at risk for low self-efficacy and decreased interest in STEM because of prevailing stereotypes of what scientists do and do not look like (Aurah, 2017; Chan, 2022; Hill et al., 2018; Piatek-Jimenez et al., 2018). A lack of role models can negatively affect students' sense of belonging in STEM majors by contributing to imposter syndrome, which is heralded by a lack of self-efficacy (Vergauwe et al., 2015). The near-peer role modeling aspect of Science Is Fun is also designed to support the development of fourth-grade students' science self-efficacy through the positive social persuasion of the near-peer role models encouraging and supporting fourth-grade students' efforts to engage in science throughout the demonstration-experiments (Doménech-Betoret et al., 2017). The social persuasion of the near-peer role models can provide encouragement and positive emotional experiences, which may be needed when students are confronted with new and challenging information (Kartimi et al., 2021; Renninger & Shumar, 2002).

“The general idea of self-concept usually refers to Bcollections of beliefs that individuals holdabout themselves (Geertje et al. 2010). For example, self-efficacy would be a particular type of self-concept that normally Brefers to individuals’ beliefs about their ability to successfully produce outcomes (Renninger and Hidi 2016, p. 82). Very often, in educational studies, it is measured by asking individuals to compare themselves with other people or groups and/or with the abilities that they are assumed to have. In this context, to demonstrate a relatively high self-concept, Bone must achieve more with equal effort or use less effort than do others for an equal performance^ . (Nicholls 1984, p. 328) Thus, and since the focus of our study is S&T, we might infer the latent variable self-concept with items such as BCompared to all other students, I consider myself to be (very weak / very good) in S&T.

This relative perception of ability is usually considered as a rather stable trait, but which can also be influenced by the amount of experienced difficulty / easiness in resolving day-to-day tasks. It is believed to be very easy to weaken if one feels that he/she has not satisfied an authority figure’s explicit expectations. Since grades allow students to compare each other, they are also naturally expected to affect it. However, even though we can easily hypothesize that achievement should be a predictor of self-concept, it is also sometimes found to be a product of it (Helmke and van Aken 1995), especially with younger students (Ganley and Lubienski 2016). Indeed, it appears reasonable to believe that having a strong self-concept encourages engagement, which in turn favors success. But Ganley & Lubienski argue that most existing studies of the relation between confidence and achievement that use large samples and rigorous statistical techniques support a reciprocal effects model^ (2016, p. 184). A reciprocity of a similar kind has been observed in mathematics education between self-concept (self-efficacy) and the construct of interest (Marsh et al. 2005). Whether this reciprocity is balanced is however contested. Indeed, sometimes an Binterest towards self-efficacy predominance was recorded (at the secondary level; N = 6908; grades 7–10) (Bong et al. 2015), while in other instances, the opposite was also observed (Ganley and Lubienski 2016, p. 188), although with weaker beta values (0.12). We therefore agree with Bong’s premise the causal predominance between them remains contested (Bong et al. 2015, p. 37). Naturally, self-concept is also considered a good predictor of the intention to pursue science, although not as strong as interest. In a previously published cluster analysis, we suggested that this may merely be due to ordinary preferences. Indeed, about 25% of students appear to have a strong S&T self-concept but just lack enough interest needed to develop the intention to pursue. Called confident indifferents, these usually performant students were hypothesized to B simply prefer other subjects over S&T(Potvin and Hasni 2017a, p. 16).”

“When we analyze national and state curricula around the world, we can see a rather large variety of objectives that are pursued by S&T schooling (citizenship, democratic, environmental, etc.). However, the intention to ensure the continuity of a scientific and engineering workforce is almost always present, while however not often being dominant. Nonetheless, the intention to pursue S&T studies and careers that is expressed (or not) by the young generation is an important issue that has been studied by the science education research community. It is often measured with very simple agreement items such as BI intend to pursue S&T studies and is also often considered as a valuable symptom of interest. As a latent construct, the intention to pursue studies and careers in a certain discipline (rather than in others) appears to cultivate weak or, maybe more likely, complicated interactions with interest and self-concept. For example, we have previously shown that establishing profiles of interest crossed with self-concept could better predict the intention to pursue, rather than merely considering these variables as having linear effects (Potvin and Hasni 2017a).

It could also be hypothesized that these interactions would differ substantially between young children and near-adults, the latter being under more pressure to make decisions about their future. These decisions are considered as being influenced both by interest and self-concept, because not only do students decide according to their attraction for a topic but also according to the evaluation of their own capacity to carry out and succeed in sometimes reputed difficult post-secondary programs. For university students, the effects of self-efficacy on the choice of a science-related career have however appeared (at least one time) to be mediated by interests (Lent et al. 1991). We thus believe that more longitudinal research efforts are needed to enlighten the complex causal links that can exist between students’ vocational choices and other perceptual constructs.”

Mathematics differs from other domains of scientific knowledge in that mathematical objects are non-physical and abstract. Thus, they can be accessed through representations (Duval, 1999). Semiotic representations refer to groups of signs collected together into families (e.g., language, numeric writing, symbolic writing) (Duval, 1999). The same mathematical object may be represented by different semiotic representations that do not share the same characteristics but represent the same content. Thus, the content of semiotic representations must be distinguished from the mathematical objects they represent (Pino-Fan, Guzmán, Duval, & Font, 2015). According to Duval, a semiotic system of representation can be considered a register of semiotic representation when it satisfies three cognitive activities inherent to all representations: (1) The representation constitutes a set of perceptible signs that allow one to identify them as representative of something in a given system. (2) The representation can involve the activity of treating the problem through transformations executed in the same semiotic system. (3)

The representation can involve conversion, defined as a shift from one system to another system. The ability to shift from one register to another is considered an essential part of mathematical problem solving (Duval, 1999). Thus, to analyze the complex and specific thinking processes underlying mathematical activity, we must take into account the differences between the various semiotic representation systems (Duval, 2006).

Serious games are generally defined as digital software the primary purpose of which is learning rather than entertainment (Klopfer, Osterweil, & Salen, 2009). They could be a beneficial alternative to other instructional methods (Griffiths, 2002; Munienga & Muhandji, 2012; Scanlon, Morris, Di Paolo, & Cooper, 2002) and could transform education (Shaffer, Squire, Halverson, & Gee, 2004) because: (1) simulation and video games let players participate in worlds otherwise inaccessible to them and thus develop new situated understanding; (2) video games make it possible for players to participate in very large scale communities of practice and to learn by doing the ways of thinking that organise those practices. With regard to the role of serious games in education, some scholars (e.g. Prensky, 2001) have even argued that developing digital-based educational games is a 'moral imperative', as learners of the new generation do not respond as effectively to more conventional instruction.