Revue internationale du CRIRES
Innover dans la tradition de Vygotsky
CRI_SAS international Journal
Vygotsky's Heritage: Innovation in Education

Understanding co-creativity in real-world problem solving in project-based learning in higher education

Guillaume Isaac, Margarida Romero et Sylvie Barma

Volume 6, numéro 3, 2022

Créativité, activités et éducation
Creativity, activities, and education

URI : https://id.erudit.org/iderudit/1094256ar
DOI : https://doi.org/10.51657/ric.v6i2.51585

Aller au sommaire du numéro

Éditeur(s)

Centre de recherche et d'intervention sur la réussite scolaire

ISSN

2291-6717 (numérique)

Découvrir la revue

Citer cet article

Isaac, G., Romero, M. & Barma, S. (2022). Understanding co-creativity in real-world problem solving in project-based learning in higher education. *Revue internationale du CRIRES / CRI_SAS international Journal*, *6*(3), 86–99. https://doi.org/10.51657/ric.v6i2.51585

Résumé de l'article

La présente étude constitue un effort préliminaire pour cadrer la co-créativité, l'apprentissage par projet et la résolution de problèmes issus du monde réel sous la perspective de la théorie historico-culturelle de l'activité. Cet article propose d'établir la co-créativité comme une activité de formation de concepts en milieu naturel et une activité de médiation collective adaptée à la résolution de problèmes issus du monde réel en contexte d'enseignement supérieur. A ce titre, cette étude vise à faire le pont entre la co-créativité et le monde réel, par les connaissances, compétences et actions acquises en contexte de résolution co-créative de problèmes en enseignement supérieur.

UNDERSTANDING CO-CREATIVITY IN REAL-WORLD PROBLEM SOLVING IN PROJECT-BASED LEARNING IN HIGHER EDUCATION

Guillaume Isaac guillaume.isaac@univ-cotedazur.fr
Étudiant au doctorat
Université Côte d'Azur

Margarida Romero margarida.romero@univ-cotedazur.fr
Professeure
Université Côte d'Azur

Sylvie Barma sylvie.barma@fse.ulaval.ca
Professeure
Université Laval

Abstract

The present study constitutes a preliminary effort to frame co-creativity, project-based learning and real-world problem-solving under a cultural historical activity theory framework. The paper establishes co-creativity as collective concept formation *in the wild* and collective mediation as primary elements for the study of real-world problem solving in higher education. This study aims at bridging gaps between co-creative real-world problem solving in higher education and knowledge, competency, action between higher education and the real world.

Keywords: creativity, co-creativity, problem solving, real-world problems, cultural historical activity theory, concept formation, higher education, project-based learning

Résumé

La présente étude constitue un effort préliminaire pour cadrer la co-créativité, l'apprentissage par projet et la résolution de problèmes issus du monde réel sous la perspective de la théorie historico-culturelle de l'activité. Cet article propose d'établir la co-créativité comme une activité de formation de concepts en milieu naturel et une activité de médiation collective adaptée à la résolution de problèmes issus du monde réel en contexte d'enseignement supérieur. A ce titre, cette étude vise à faire le pont entre la co-créativité et le monde réel, par les connaissances, compétences et actions acquises en contexte de résolution co-créative de problèmes en enseignement supérieur.

Mots-clés : créativité, co-créativité, résolution de problèmes, problèmes issus du monde réel, théorie historico-culturelle de l'activité, formation de concepts, enseignement supérieur, apprentissage par projet

Note d'auteur

Toute correspondance concernant cet article doit être adressée à Guillaume Isaac (guillaume.isaac@univ-cotedazur.fr)

Runaway objects and wicked problems

In the first edition of *Learning by expanding*, Yrjö Engeström highlighted the increasing importance of the many challenges faced by society and humanity at large (2015). Far from being a scaremonger or a doomsayer, Engeström foresaw the importance of phenomena that were reaching beyond the history of societies. Borrowing from Giddens the concept of *runaway object* (2003) to describe diverse real-world problem solving (RWPS) such as climate change, homelessness or pandemics, the *wicked problems* (Rittel & Webber, 1974) or *wicked messes* (Mitroff, 2020) of contemporary society have come to be perceived as generative in Cultural-Historical Activity Theory (CHAT) – participating to the production of alternatives to capitalism (Engeström, 2020). Under this perspective, wicked problems are a type of runaway objects which in contemporary society allow human beings to create and transform themselves by changing nature through the world of cultural objects (Miettinen, 2001). This study focuses on the implications of wicked problems as a type of runaway object in higher education.

Implications of real-world problem solving for higher education

According to Engeström (2020) both cognitive science and educational research have failed to recognize the implications of runaway objects as ways to cope with the world through manipulation of increasingly complex and demanding concepts. These concepts are multi-faceted and ill-bounded objects, ideas, and practices which human beings need to understand and conceptualize if they are to transform them. On the one hand, runaway objects and wicked problems are relevant to the unfolding of human emancipation and agency under stressful and tense situations (Beghetto, 2021); on the other hand, they also represent major challenges to the development of the person as a whole in volatile, complex, uncertain and ambiguous environments in which "big picture thinking" is required to strive (Boix Mansilla & Schleicher, 2022). Indeed, the acquisition of generic competences such as collaboration, creativity, and communication to address major societal, technical or environmental complex problems (World Economic Forum, 2015) are a major condition to ensure ongoing economic prosperity (European Commission, 2017). Among the main purposes of the development of transversal competences, complex problem solving has been identified as a priority (OECD, 2017).

Real-world problem solving

According to Sarathy (2018), real-world problems are a distinctive type of complex problems from those that occur in a classroom or in a laboratory during an experiment (2018); complex problems are ill-defined, open-ended and are not expected to be solved through routine thinking (Steiner, 2009). As a result, the solving of real-world problems relies on solutions not yet available to the solver and therefore on novel connections of different planes of a given problem. As such, Sarathy characterizes real-world problems as dynamic, discontinuous, and ruled by intermittent activity, composed of sub-problems, with an open-ended final issue (2018). Beyond mere complexity, real-world problems require constant interaction between the solvers and their environment; as such they display a high level of complex interactions in a system made of a

variety of participants and elements interacting at different levels. As a result, real-world problems therefore involve collectives and creativity.

Creativity in collective learning activities

Creativity is an essential element of an innovation process (Hero & Lindfors, 2019) and has been identified as a major condition for the sustaining of economic growth and prosperity (European Commission, 2020). However, the requirements for innovation within different domains are high, and are unlikely to be met by individuals on their own (Lemmetty et al., 2021); moreover, the solving of real-world problems and the development of innovation could require continuous learning, creative intention, and perseverance (Lemmetty et al., 2021; Leroy & Romero, 2021). Learning may therefore benefit from collaborative settings, as it allows participants to learn from one another and to learn how to collaborate (Stahl, 2006). Learning, creativity and collaboration therefore appear closely related to one another; yet, as noted by Sannino and Ellis, learning and creativity are less studied in collective learning activities (2015, p.1), and the potential for groups to construct knowledge by merging ideas from a variety of perspectives remains rarely tapped into. Additionally, even though interdisciplinary collaboration and Project-Based Learning (PBL) are valuable avenues to foster the ability to creatively solve problems, they still remain understudied (Warr & West, 2020).

Problem

The introduction of *real-world* or *consequential* problems (Funke, 2021) to higher education contexts presents a variety of challenges to research endeavors beyond process duration. While creativity is considered as a necessary competency in the working force to ensure economic prosperity, CHAT stresses the potential for transformation of human activity to uncover what is "not yet there" (Engeström, 2015, p. xxxiii) but is nonetheless required to cope with challenges. Although the scope and reach of both stances display different concerns and orientations, the contention of the authors is that socio-cultural perspectives, and CHAT in particular, shows relevant prospects to address the challenges presented to higher education by real-world problem solving, both from the point of view of research and from the perspective of teaching and learning. According to socio-cultural theories, both creativity and learning emerge from interactions among and between individuals and the environment and are therefore collective by nature (Lemmetty et al., 2021; Glăveanu et al., 2019).

In this respect, the authors of this study suggest CHAT may provide a framework to promote the empowerment of individuals and collectives regarding controversial issues while considering the social, cultural and organizational dimensions involved in the implementation of a *project* or the solving of a *problem* that is meaningful to the solvers; this study aims to identify some elements from CHAT to bridge gaps around the emergence of co-creative processes to solve real-world problems in higher education at the crossing sections of knowledge, competency and action; the potential of groups to construct knowledge by merging ideas coming from a variety of perspectives remains a complex endeavor, both from a laboratory perspective and from an ecological one. This study drafts a primary framework considering the following questions: to what extent does PBL allow for the introduction of RWPS in higher education? What is the role

of creativity in RWPS? To what extent is CHAT a fruitful theoretical framework to the study of such a phenomenon? To answer these questions this article is split into three sections; the first section suggests definitions from the literature on PBL and RWPS in higher education; the second section offers perspectives to link real-world problem solving and collaborative creativity. Finally, the last section puts collaborative creativity under a CHAT perspective.

Project-based learning and real-world problems in higher education

PBL as an avenue to real-world problem solving in higher education

According to Prince and Felder (2006), PBL is a teaching method based on course delivery centered on a specific challenge or a complex real-world problem. Students are consequently accompanied or mentored to learn the theories, facts, skills and concepts they feel they are missing to meet the challenge or solve the problem. A variety of approaches have been exposed in the literature, including discovery learning, inquiry-based learning, problem-based learning, project-based learning, case-based learning, just-in-time-teaching, and active cooperative learning.

These approaches share several common features according to Krauss and Boss (2013): (a) students grapple with *real-world concerns* and aim at essential understandings; (b) students *choose* the way they frame the issues they are dealing with from their own experience and perspective, which causes them (c) to inquire and engage with *complexity*. It involves (d) a process of *learning* together and from one another to reach the goal that was collectively chosen. Learning is rooted in real experiences, and as such it is (e) *meaningful* to participants beyond school. Finally, students are (f) *personally affected* by their participation and are therefore likely to remember their experience. As a result, methods of teaching such as PBL appear as a valuable avenue for introducing real-world problems to a higher education audience, while promoting transversal competencies such as collaboration and self-directed learning; the solving of real-world problems may also require creativity to resolve authentically complex situations

.

Framing PBL under a CHAT perspective: a missing link between creativity and learning

Nolen and colleagues (2020) deem project-based learning to be a meaningful way of involving students across disciplines with deep and complex problems; by way of example, the authors in particular stress the relevance of multidimensional problems such as environmental issues. Besides introducing complexity, controversial issues are meaningful to the solvers and therefore address the criteria of meaningfulness and personal involvement (Krauss & Boss, 2013).

Problem solving and CHAT

Faithful to the perspectives and the specificities of a CHAT framework, Jurdak (2016) characterizes problem solving as *goal-oriented*: it is aimed at acting or moving towards a solution to resolve a certain difficulty. It is *artifact-mediated*: the solution to a problem may require the use of available or made-up tools in the environment of the solver. Problem solving is *dialectical:* it aims at removing conflicts arising from inner contradictions between and among the subject, the mediating artifacts, and the object of the activity. Problem solving is a *temporal* and a *historical*

process: it occurs in a particular space-time context, and it is not likely to be grasped fully without considering the relevant history of the problem in the specific local context in which it occurs. Finally, problem solving is a *cultural* process: its object as an activity derives its meaning from the cultural context and the artifacts that are used to reach the goal which are also cultural products. As a final addition, problem solving, when ill-defined and open-ended, could also be said to involve a moral dimension as an activity involving conscious decisions and action to stop relying on pre-existing scripts, procedures or rules (Mahon et al., 2017).

Implications for higher education

According to Jurdak (2016) solving problems from the real-world in schools requires a plurality of voices to address complexity: students are engaged in problem-solving tasks as part of an instruction program aiming at the application of previous knowledge while engaging with professionals and experts beyond the confines of higher education. The components and subcomponents of the problem at hand are shaped both by educational and real-world contexts, each influencing the perception participants have of the other in a dynamic fashion. In the context of institutional or organizational activities managed by professionals, individuals define problems according to their work environment, whereas in school teaching, the decision as to what constitutes a problem is pre-established by teachers or by instructional support (Jurdak, 2016). The navigation between problems and solutions involving a variety of participants is one of the most difficult and critical dimensions to be addressed in PBL. In the face of unpredictability and uncertainty while addressing open-ended issues, participants are expected and required to use creativity in the resolution or solving of problems as they repeatedly cross the boundaries between the activities of school and work and between problems and solutions (Koppenhagen et al., 2021).

To sum up, PBL may offer a fruitful framework in higher education to provide an incentive for participants to expand their education (Jones, 2014) at the boundary of education and professional domains (Jurdak, 2016) through activities that are meaningful to them with the potential to benefit society at large. However, the confrontation to open-ended, ill-defined problems where the solution may not be known in advance calls for an element of creativity (Sarathy, 2018). The Four C model of creativity is suggested in the following section as a framework for the understanding and application of creativity to real-world problems.

Real-world problem solving requires creativity and collaboration

As daunting as environmental, sanitary or societal issues might appear, real-world problems do not always require the intervention of prominent individuals – geniuses – to be solved; however, as the complexity of problems and challenges faced by societies keeps increasing, *creative* solutions are urgently needed (Funke, 2021) with the imperative to be implemented in an ethical manner (p. 16). This requires adaptation, a complex collection of traits Sternberg dubs *transformational intelligence.* To him, *transformational intelligence* aims at positively transforming the world for the greater good of the greatest number (2021, p. 75). *Transactional intelligence*, on the other hand, is based on exchange of resources, a transaction of effort for personal benefit (ibid). The former, *transformational intelligence*, is highly relevant to the line of thinking developed in this study in spite of the fact that it is described as a personal trait rather

than a collective process; the ability and willingness to transform displays a concern for the materiality of action in the socio-cultural world, and involves other individuals; transformation therefore appears as a collective phenomenon emerging in a system; indeed, Funke (ibid) contends that the successful handling of such complex problems does not correlate with intelligence and that transversal competencies such as critical thinking, systems thinking, and managing uncertainty are better requirements (2021). Consistent with previous observations, Lemmetty and collaborators (2021) contend that the interplay of different profiles is most prevalent as no one type or assortment of skills, as high as they might be, is bound to be sufficient. Therefore, creativity, collaboration and problem solving appear as interrelated competencies in co-creative activity and call for a distinction between different types of creativity.

The Four C model of creativity

According to the Four C model of creativity, *Big-C* is defined as genetically inspired, the product of creative genius with the potential to shift fields and domains. *Big-C* represents the output of eminent individuals that were honored by time and recognized by history; its object is the work of individuals that potentially reconfigures entire fields (Sternberg & Lubart, 1999). Examples of models of Big-C include the Propulsion Theory of Creativity (Sternberg & Lubart, 1999) while *Pro-C* defines creativity as happening at an expert level that has not reached legendary status (Kaufman & Beghetto, 2009).

However, this study is concerned with different types of creative constructs to approach the ability to solve complex problems collaboratively and creatively. Namely, *little-c*, understood as creative activities conducted by individuals or collectives who may not be recognized as experts or leaders in their field; examples include Amabile's componential model of creativity (2018) which seeks to incorporate individual creativity into a model of organizational innovation through the development of relevant traits (e.g., domain-relevant, creativity-relevant and task motivation). Finally, *mini-c* involves the self-directed discovery of meaningful insights and interpretations which apply to a *learning process* (Beghetto, 2021). As such, *mini-c* and *little-c* are the type of constructs to be expected from students in higher education engaged in PBL encouraging them to trade ideas, concepts or hypotheses over the solving of a problem in tandem with representatives of a given field or domain.

Co-creativity

Describing activities at the intersection of collaboration and creativity, Romero and her colleagues (2019) describe co-creativity as "a contextual process of shared conception and creation of an idea or a solution to a problem which is deemed novel, appropriate and relevant by a group of reference" (p. 199). According to this definition, and considering previous definitions, co-creativity happens as the result of the fluctuation between *mini-c* and small-c in collective activity; it emerges in discourse and is mediated by linguistic and material artifacts emerging at the boundaries of a system materialized by individuals, collectives, field, and domain (Csikszentmihalyi, 2015)

.

Co-creativity as a creative collective learning opportunity

Indeed, according to Kaufman and Beghetto (2009), *mini-c* and *little-c* are particularly relevant to education contexts; when students are encouraged to be proactive towards academic subject matters in a personally meaningful way, the creative insight produced falls into the *mini-c* category. However, Big-C and *little-c* creativity can be conceptualized as existing on the same developmental continuum (Beghetto & Kaufman, 2007). The sharing of *mini-c* constructs represents a potential creative contribution to the comprehension of others potentially taking part in a learning experience outside of one's own (Kaufman et al., s. d.); it therefore provides a way to integrate creativity and learning, individual and collective learning. This integration has important implications in the context of the present study: as detailed below, it supports *mini-c* and *little-c* constructs through *creative learning* (Beghetto, 2016; 2021).

Under this perspective, *creative learning* appears as the product of the interplay between individual intrapsychological and collective interpsychological processes which could result in a novel and meaningful understanding on both levels. This perspective is strongly reminiscent of Vygotsky (1980) for whom the group – or social, or intersubjective level – is prior to the development of the individual at intrasubjective level. In this respect, collaboration is the result of collective mediation through *discourse* and *artifacts*.

Stressing the "*co*" in co-creativity

Although creativity has mostly been studied under an individual perspective (Miettinen, 2013), the framework of co-creativity exposed so far illustrates the fact that when complex problems require collaboration and creativity, creativity is necessarily a social process supported by concepts used as mediational tools; in the words of Romero: "This definition of the creative process fostered by a situational problem coincides with Vygotsky's concept of double simulation, according to which learners overcome critical conflicts by making use of cultural artifacts in order to create a solution that emancipates them from the problem situation" (2020, p.2).

To sum up, real-world problems have been shown to have the potential to involve higher education students into meaningful, topical and controversial issues with the possibility to involve and engage students into expanding learning; this learning is of a different type than typical learning and contrasts with the student-centered approach classically adopted in higher education where the result of learning is affecting the behavior and cognition of learners (Engeström & Sannino, 2010). By participating in learning at the boundaries of higher education and work through a social process, students may engage in a process with the potential to transform their activity through a *learning activity*. The concept of activity is further developed in the section below.

Co-creativity and learning activities

According to Engeström (2015), human learning happens through non-conscious learning operations and actions embedded in other activities, above all in work. In this respect, human learning is unintentional and inseparable from the work activity. From the point of view of CHAT, the object of learning activity is a "societal productive practice", or the "social life-world" (p. 99),

which therefore might happen more closely in work-related contexts than it does in school environments. According to the author, learning in school is mostly concerned with the oral or written reorganization of pre-existing texts; it is therefore concerned in priority with closed problems; on the other hand, tensions in the work environment require to think flexibly in trying to solve problems, which requires a particular kind of activity: a *learning activity* (p.91). This concept is pivotal to understanding the relation between real-world problems from a higher education perspective, although it deepens the meaning of the concept of learning usually in use in higher education and approximates it to the notion of transformation and expansion of human activity. From the point of view of this study, this is therefore a collaborative, creative and collective endeavor closely matching the definition of co-creativity. The learning activity concept described by Engeström (2015) frames it as emerging from the tension between higher education and work, aiming at societal and material changes, which PBL may afford.

Creative real-world problem solving from a CHAT perspective

The double nature of CHAT: *understanding* or *transforming*

Cultural-historical activity theory focuses on two possible objects: *understanding* and *transforming* practice through human actions occurring in a social setting over time. The theory holds the concept of *activity*, understood as collectively motivated human activity (Roth et al., 2009) as its main unit of analysis. According to Lektorsky (2009), the concept of activity stems from the work of Leontyev (1977) and Davydov (1990) who showed that understanding activity in terms of actions, operations, motives, goals and tasks is insufficient; it also requires to take into account *values* and *norms*. Used as a unit of analysis, activity therefore opens up the components of a system by offering a way to conceptualize the mediation between its different poles.

When trying to *understand* a complex phenomenon such as co-creative problem solving, the concept of activity affords an organizing *frame* circumventing the phenomenon (Romero et al., 2021). However, CHAT is also described in the literature as a theory affording participants with a *transformation* process engendered by inner contradictions in human activities in an evolving environments. The pressure of inner contradictions between the different elements ruling a system makes both the participants and the system evolve and transform to adapt to new circumstances. These processes are carried out by the cultural tools that they are mediated by.

Additionally, according to Jurdak (2016), an *activity* has two interdependent dimensions: an *external* one as it brings humans in contact with objects, a process which redirects change and enriches the activity. The second dimension is an *internal* level, formed because of the internalization of external processes. Activity is therefore both a *psychological* and *socio-cultural* process. The interplay between internalization and externalization and the relation of mutual dependency between both establishes an important connection between the notion of creativity and the notion of activity along both dimensions; internalization of external processes can never be understood as mere reproduction and always implies a creative dimension on behalf of the subject, while every instance of an activity implies considering new circumstances which also implies a creative effort (Lektorsky, 2009).

Activity and creativity: the dialectic relationship between subject and object

Davydov (1990) demonstrated that collective activity is not only an expansion of individual activity. Collective activity includes reciprocal activity and reciprocal actions. The interaction of its participants can be understood as communication processes; the participants must constantly discuss issues with each other and engage in a dialogue or polylogue in order to understand each other's positions and to learn to see themselves through each other's eyes - that is, to cultivate within themselves the quality of self-reflection (Lektorskii, 2004, p.20). But if the collective activity includes the interaction of its participants, and in particular, their communication, then the understanding of the activity itself also changes. The actions that are embedded in the interaction with the other person are not the same as the actions required to produce an object or change an objective situation. "For interaction with another presupposes that the latter is the same kind of independent subject as I myself. The result of such actions on my part does not depend on me alone; I cannot fully control it" (p. 20). According to Lektorskii, this new version of the psychological theory of activity significantly changes its character and potential.

The concept of mediation and remediation serves to frame creativity and learning as possible outcomes in an activity system, which by seeking to transform its object also transforms its subjects. While creativity might be considered as the desirable quality of the outcome of an activity such as solving open-ended and ill-defined problems, Lektorsky (ibid) stresses the fact that despite the outcome, the collective dimension of activity involves de facto a level of creativity which may manifest in every mediation at the pole of a given activity system. As a result, the mediation and remediation processes significantly expand on the trading of *mini-c* and *little-c* in co-creative activity and creative learning. Creativity from a CHAT perspective is therefore dialectically dependent on subject and object in activity: all creative processes have a collective dimension; all creativity is co-creative to some extent. The transforming potential through the overcoming of inner contradictions between the elements of a system echoes a number of elements from PBL, real-world problems as well co-creativity in that it deepens the link between creativity and learning.

Beyond or below concept formation: remediation to produce cultural novelty

CHAT provides a powerful lens through which to consider the interrelations between different poles ruling an activity system while taking into account personal and collective dimensions of the activity, environment, and historical development. Creativity in collective activities from this perspective arises from a need to change and adapt activity due to the pressures exerted by inner contradictions in a system. For Lektorsky (2009), this presupposes an effort of reflection to produce new mediations which afford a system with the possibility to change or actualize itself while remaining useful within its original framework. This perspective complements the frame afforded by the *mini-c* to *little-c* continuum mentioned above; remediation allows for the framing and reframing of either *mini-c* or *little-c* among collectives and therefore may serve as a valid analytical tool for creative activity in collectives.

Co-creativity as collective concept formation activity - with a potential for transformation?

Framing co-creativity as a systemic phenomenon and establishing it as happening at the interaction of different activity systems has several implications; first, it underlines the prevalence of a collective unit of analysis to its study; the following section intends to advance it one step further by framing co-creativity as collective creative concept formation. Second, it asks the question of the nature of the output of these collectives when facing such conflicting objects as real-world problems. As far as concepts are concerned in higher education settings, a primary distinction is important to make: Greeno (2012) distinguishes *formal* and *functional* concepts, the latter being a contrasting notion rather than an empirically stable one with the potential to produce high levels of cultural novelty. The building of functional concepts calls upon creativity in collectives and therefore relies less on individual traits of subjects involved in a particular activity aiming at creative actions or products. In this respect, collective concept formation is a matter of *collective learning* and a creative process of generating cultural novelty. Concept formation as a process transcends the boundaries between cognitive and material and this process happens through the use and combination of symbols, words and languages; it is grounded in embodied action and is mediated by artifacts in the material world (Engeström, 2013).

To sum up, we believe the five guiding ideas for concept formation from Engeström (2020) to illustrate the main ideas expressed so far to expand PBL, real-world problems and co-creativity into CHAT territory. When considering creative problem solving in collaborative settings, co-creativity is understood as emerging from a *collective activity system* that evolves *historically*; the concepts formed in collective activity can be defined according to qualitatively different *types* of concepts, namely formal and functional concepts. Concepts are formed by ascending from the abstract to the concrete and they are *polyvalent*, *debated* and *dynamic*. Finally, co-creative concept formation could be considered as intertwined with the generation of "*transformative agency by double stimulation"* (Sannino, 2020, p.2). This section has allowed to highlight salient common points between PBL, real-world problems and creativity; co-creativity has been identified as collaborative concept formation, and the social, systemic and emergent features of co-creative activity have been identified.

Conclusion

Giving students in higher education the opportunity to solve authentic ill-defined problems while rubbing shoulders with peers and professionals is a process ripe with tensions and difficulties on a teaching and learning level as well as on a research level. Following Jurdak (2016), these difficulties can be summed up as follows: the solving of real-world problems across multiple boundaries at the intersection of multiple activity systems implies *discontinuity* in action or interaction as participants cross over back and forth. Maintaining or restoring continuity between activity systems requires *energy* and *will* from participants on all sides of interacting systems. The formation of *functional concepts* (Engeström, 2020) through collective mediation and remediation to reach conceptual (Lektorsky, 2009) and cultural novelty (Engeström, 2020) is a complex, time-consuming and often messy process that require negotiation and hybridization across different positions, practices and perspectives among participants. The interactions between participants in RWPS are structured using mediating artifacts and learning mechanisms at the boundaries; RWPS is a future-oriented process with potential to trigger agentive actions (Jurdak, 2016). Yet, as constraining as PBL or RWPS might be to integrate and blend to higher education systems, they

also present students from a variety of disciplines with an opportunity to learn and practice valuable twenty first century competencies and may also produce further opportunities to expand their education beyond the margins of regular courses and experiences. It may also offer the opportunity to expand their activity beyond school while practicing agentive actions. As such, co-creative real-world problem solving as a research object may answer the call from Engeström (2020) to extend the study of concept formation to schools and other educational institutions. Finally, we situate this study within a larger call for more studies on double stimulation (Isaac et al., 2022) and suggest foundations for a framework which further contributes to articulate co-creative real-world problem solving in relation to double stimulation and transformative agency.

References

Amabile, T. M. (2018). *Creativity In Context : Update To The Social Psychology Of Creativity* (First edition., Vol. 1-1 online resource : text file, PDF). Taylor and Francis; WorldCat.org. https://www.taylorfrancis.com/books/9780429501234

Beghetto, R. A. (2016). Creative learning : A fresh look. *Journal of Cognitive Education and Psychology*, *15*(1), 6-23.

Beghetto, R. A. (2021). How times of crisis serve as a catalyst for creative action : An agentic perspective. *Frontiers in Psychology*, *11*, 3735.

Beghetto, R. A., & Kaufman, J. C. (2007). The genesis of creative greatness : Mini-c and the expert performance approach. *High Ability Studies*, *18*(1), 59-61.

Boix Mansilla, V., & Schleicher, A. (2022). *Big picture thinking* (p. 106). Organisation for Economic Co-operation and Development. http://www.pz.harvard.edu/sites/default/files/WEB_Big%20Picture%20Thinking_how%20to%20educate%20the%20whole%20person%20for%20an%20interconnected%20world%5B99%5D.pdf

Davydov, V. V. (1990). *Types of Generalization in Instruction : Logical and Psychological Problems in the Structuring of School Curricula. Soviet Studies in Mathematics Education. Volume 2.* ERIC.

Engeström, Y. (2013). Collective Concept Formation as Creation at Work. *Learning and collective creativity: Activity-theoretical and sociocultural studies*, 234.

Engeström, Y. (2015). *Learning by expanding*. Cambridge University Press.

Engeström, Y. (2020). Concept formation in the wild : Towards a research agenda. *Éducation et didactique*, *14-2*, 99-113. https://doi.org/10.4000/educationdidactique.6816

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning : Foundations, findings and future challenges. *Educational Research Review*, *5*(1), 1-24. https://doi.org/10.1016/j.edurev.2009.12.002

European Commission. (2017). *Communication from the commission to the European parliament, the Council, the European economic and social committee and the Committee of the regions on a renewed EU agenda for higher education* (COM(2017) 247 final; p. 12). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017DC0247

European Commission. (2020). *Communication from the commission to the European parliament, the Council, the European economic and social committee and the Committee of the*

regions A new ERA for Research and Innovation (COM(2020) 628 final; p. 22). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A628%3AFIN

Funke, J. (2021). It Requires More Than Intelligence to Solve Consequential World Problems. *Journal of Intelligence*, *9*(3). https://doi.org/10.3390/jintelligence9030038

Giddens, A. (2003). *Runaway world : How globalization is reshaping our lives*. Taylor & Francis.

Glăveanu, V. P., Ness, I. J., Wasson, B., & Lubart, T. (2019). Sociocultural Perspectives on Creativity, Learning, and Technology. In C. A. Mullen (Éd.), *Creativity Under Duress in Education?* (Vol. 3, p. 63-82). Springer International Publishing. https://doi.org/10.1007/978-3-319-90272-2_4

Haapasaari, A., Engeström, Y., & Kerosuo, H. (2016). The emergence of learners' transformative agency in a Change Laboratory intervention. *Journal of education and work*, *29*(2), 232-262.

Hero, L.-M., & Lindfors, E. (2019). Students' Learning Experience in a Multidisciplinary Innovation Project. *Education & Training*, *61*(4), 500-522. eric.

Isaac, G., Barma, S., & Romero, M. (2022). Cultural historical activity theory, double stimulation, and conflicts of motives in education science : Where have we been? (2012-2021). *Revue internationale du CRIRES : innover dans la tradition de Vygotsky*, *5*(2), 86-94. https://doi.org/10.51657/ric.v5i2.51287

Jurdak, M. (2016). Activity Theory as a Foundation of Real-World Problem Solving in School Mathematics. In M. Jurdak, *Learning and Teaching Real World Problem Solving in School Mathematics* (p. 49-78). Springer International Publishing. https://doi.org/10.1007/978-3-319-08204-2_4

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond Big and Little : The Four C Model of Creativity. *Review of General Psychology*, *13*(1), 1-12. https://doi.org/10.1037/a0013688

Kaufman, J. C., Beghetto, R. A., & Roberts, A. M. (s. d.). Creativity in the Schools : Creativity Models and New Directions. In *Handbook of Positive Psychology in Schools* (p. 335-345). Routledge.

Koppenhagen, F., Blümel, T., Held, T., Wecht, C., & Kollmer, P. D. (2021). The challenging combination of agility and convergence in hybrid product development processes : An empirical analysis of Stanford's ME310 process model. *Proceedings of the Design Society*, *1*, 2991-3000.

Krauss, J., & Boss, S. (2013). *Thinking through project-based learning : Guiding deeper inquiry*. Corwin Press.

Lektorskii, V. (2004). Activity-based approach : Death or Rebirth. *Metodologicheskie problemy sovremennoy psikhologii*.

Lemmetty, S., Collin, K., Glăveanu, V. P., & Forsman, P. (2021). *Creativity and Learning : Contexts, Processes and Support*. Springer.

Leroy, A., & Romero, M. (2021). *Teachers' Creative Behaviors in STEAM Activities With Modular Robotics*. *6*, 152.

Mahon, K., Kemmis, S., Francisco, S., & Lloyd, A. (2017). Introduction : Practice theory and the theory of practice architectures. In *Exploring education and professional practice* (p. 1-30). Springer.

Miettinen, R. (2001). Artifact Mediation in Dewey and in Cultural-Historical Activity Theory. *Mind, Culture, and Activity*, *8*(4), 297-308. https://doi.org/10.1207/S15327884MCA0804_03

Mitroff, I. I. (2020). Corona virus : A prime example of a wicked mess. *Technological Forecasting and Social Change*, *157*, 120071. https://doi.org/10.1016/j.techfore.2020.120071

Nolen, S. B., Wetzstein, L., & Goodell, A. (2020). Designing Material Tools to Mediate Disciplinary Engagement in Environmental Science. *Cognition and Instruction*, *38*(2), 179-223. https://doi.org/10.1080/07370008.2020.1718677

OECD. (2017). *PISA 2015 Results (Volume V) : Collaborative Problem Solving*. OECD. https://doi.org/10.1787/9789264285521-en

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods : Definitions, comparisons, and research bases. *Journal of engineering education*, *95*(2), 123-138.

Rittel, H. W., & Webber, M. M. (1974). Wicked problems. *Man-made Futures*, *26*(1), 272-280.

Sannino, A., & Ellis, V. (2015). *Learning and Collective Creativity : Activity-Theoretical and Sociocultural Studies*. Routledge. https://www.routledge.com/Learning-and-Collective-Creativity-Activity-Theoretical-and-Sociocultural/Sannino-Ellis/p/book/9781138941694

Sarathy, V. (2018). Real World Problem-Solving. *Frontiers in Human Neuroscience*, *12*, 261. https://doi.org/10.3389/fnhum.2018.00261

Stahl, G. (2006). *Group cognition : Computer support for building collaborative knowledge*. MIT Press.

Steiner, G. (2009). The Concept of Open Creativity : Collaborative Creative Problem Solving for Innovation Generation-a Systems Approach. *Journal of Business & Management*, *15*(1).

Sternberg, R. J. (2021). Transformational vs. Transactional deployment of intelligence. *Journal of Intelligence*, *9*(1), 15.

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity : Prospects and paradigms. *Handbook of creativity*, *1*, 3-15.

Warr, M., & West, R. E. (2020). Bridging Academic Disciplines with Interdisciplinary Project-Based Learning : Challenges and Opportunities. *Interdisciplinary Journal of Problem-based Learning*, *14*(1). eric. https://acces.bibl.ulaval.ca/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1257972&site=ehost-live

World Economic Forum. (2015). *New vision for education : Unlocking the potential of technology*. British Columbia Teachers' Federation Vancouver, BC.