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► To cite this version:

Brigitte Grugeon-Allys, Elann Lesnes-Cuisiniez, Fabrice Vandebrouck. Impact of online automated learning path on student learning: the MindMath project in elementary algebra. 14th International Congress on Mathematical Education, Jul 2021, Shanghai, China. hal-03317785

HAL Id: hal-03317785

<https://hal.science/hal-03317785>

Submitted on 7 Aug 2021

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IMPACT OF ONLINE AUTOMATED LEARNING PATH ON STUDENT LEARNING: THE *MINDMATH* PROJECT IN ELEMENTARY ALGEBRA

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In this paper, we address TSG25's first theme: "Technology in lower secondary education as a scientific endeavor". The automated digital learning path model presented in this paper concerns elementary algebra for French middle school students (12-15 years old). We design tasks for the MindMath platform to favour students' algebraic thinking. The modelling of tasks, using variables, their selection and use to design learning path, are based on an epistemological reference of the algebraic domain. We introduce variables, such that, for a given learning goal, they are assigned values based on the gap between the student's algebraic skills and the knowledge targeted in order to define a new exercise that can help close this gap.

CONTEXT OF THE STUDY

We propose an exercise model taking into account a student model in order to design and implement learning paths adapted to the students' competencies cognitive profile in a given mathematical field. This research is based on the results of the *Pepite* project in elementary algebra (Grugeon-Allys & al., 2018). *Pepite* aims to design and develop a global and multidimensional diagnostic model of algebraic knowledge in order to propose learning paths adapted to the learning needs of students (Pilet, 2015). This diagnosis, based on a cognitive, epistemological and anthropological approach, aims to evaluate students' procedures by taking into account the nature of errors made in elementary algebra and their conceptual development. The exercises were implemented on the LaboMep online platform used by secondary school teachers. While a profile is automatically computed when a student takes the *Pepite* test, the learning paths are fixed. Therefore, an additional study specifying the exercise and learning path models is required to automate the generation and selection of exercises. The MindMath project aims to implement exercise and learning path models on a gamified and adaptive platform for learning elementary algebra and plane geometry in middle school (7th-9th grades). The platform relies on a spreadsheet and dynamic geometry software.

In the rest of this communication, we will motivate the exercise model with an example. We will answer the following question: how can some constructs of theoretical frameworks (Anthropological Theory of the Didactic (Chevallard, 1999) and Activity Theory (Vandebrouck, 2013)) be used to build exercise and learning path models to improve students' learning?

THE THEORETICAL AND METHODOLOGICAL FRAMEWORK

An example to motivate the design of the model

We consider the exercise “Develop the literal expression $2(x+3)$ ” and a student's solution: “ $2(x+3) = 2x+3 = 5x$ ”.

How to characterize the exercise? This exercise involves the “Developing an expression” category of exercise. This first-order expression is a product of a number by a sum of general form $a(bx+c)$. We expect middle schoolers to solve it using the single distributive property.

How to choose the next exercise in the learning path according to the student's answer and profile? This student does not seem to understand the status of the letter. Indeed, he or she uses the single distributive and reduction properties incorrectly, as he or she was doing arithmetics. We present three levels of decision-making, in first time to provide feedback on the student's answer related to their algebraic skills, and in second time choose the next exercises of the learning path (theoretically based in III):

- At the exercise level: it is possible to propose a counter-example (with the spreadsheet) to invalidate the student's answer and, if needed, to provide mathematical elements relating to operations (by writing $2(x+3)$) and the single distributive property. These choices are based on the epistemological study and the role of technologies in the learning of algebra.
- At the type of exercise “develop an expression” level: selection of the next exercise of the learning path from other expressions of the type $a(bx + c)$, for example, $3(2x-3)$, to work on the old knowledge on operations and relative numbers. Then, if the student succeeds, other development exercises based on the structures $(ax+b)(cx+d)$, $e(ax+b)(cx+d)$, $(ax+b)(ax-b)$, $(ax+b)^2$, $(ax-b)^2$, $e(ax+b)^2$, $e(ax-b)^2$ are proposed to work on the double distributive property and enrich the techniques by tweaking the didactic variables (see III).
- At the field level: if the student fails, a task that falls under another type of exercise is proposed. Here, taking into account the student's difficulties, the “generation of expressions” exercise type would be more appropriate.

This analysis involves different didactic concepts from the theoretical frameworks presented below.

Model for describing knowledge

To design tasks, we rely on an anthropological approach (Chevallard, 1999) as the nature of mathematical contents depends on the institution on which we depend and which influences mathematical activity. Chevallard (1999) analyses mathematical activities in a given institution, in terms of praxeologies. A praxeology is made of four components: *type of task*, *technique* used to solve tasks, *technology* which is a discourse on the technique developed in order to describe, explain what is done, and justify techniques (properties, rules, logical arguments) and *theory* that justifies technology. Designing an assessment or learning path requires the identification of praxeologies that are representative of a mathematical field.

The praxeology of elementary algebra is based on results from the didactics of algebra (Kieran, 2007). This praxeology covers all types of tasks of the algebraic domain. We distinguish between tasks for solving problems — *generalizing*, *modelling*, *putting into equation*, *proving* — and tasks focused on calculations with algebraic expressions (*calculating*, *substituting* a number for a letter,

expanding) or equations (solving). This praxeology aims to define appropriate conditions for a reasoned and controlled algebraic calculation, based on equivalence of algebraic expressions and dialectic between numeric and algebraic treatment modes.

T4TEL model

Chaachoua (2018) defines a type of task as a set of tasks. All tasks are described by an action verb and a complement taken from the objects of the field. Chaachoua associates a system of variables to the couple (Action verb; object to which the type of task relates). Thus, Chaachoua defines a generator of type of task: GT =[an action verb, a fixed complement; a system of variables]. A given generator of types of tasks generates a structured set of types of tasks by instantiating the system of variables with different values (the verb and the object remain fixed). The exercise model presented in this communication is based on generators of types of tasks.

Student's cognitive profile - student's algebraic skills

The student's cognitive profile allows to describe student's algebraic skills on a scale of three components: ability and adaptability in the various uses of algebraic calculation, use of algebra for solving problems — *generalizing, modelling, putting into equation, proving* —, flexibility in translating a semiotic register to another (geometric figures, graphical representations, natural language, algebraic expressions) (Grugeon-Allys & al., 2018). For each of those three components, we identify different levels according to the student's algebraic conceptual development. The link and the gap between the student's algebraic skills and the targeted knowledge allows to build the learning path by choosing the most appropriate tasks according the student's learning needs.

EXERCISE AND LEARNING PATH MODELS

Exercise Model: Any mathematical exercise, being a task, involves a type of task. We specify the variables associated with generators of types of tasks (Chaachoua, 2018) on two levels:

- The first level corresponds to the variables of the type of task (V_{tt}). They specify the targeted knowledge in relation to the school level and curricula. For the example (see I), the set of literal expressions of structure: $\{a(b+c), a(bx+c), (ax+b)(cx+d), e(ax+b)(cx+d), (ax+b)(ax-b), (ax+b)^2, (ax-b)^2, e(ax+b)^2, e(ax-b)^2\}$.
- The second level corresponds to the variables of task (V_t) which aim to develop or enrich the student's procedures.

We distinguish variables of task according to their role:

- Variables V_{1t} aim to change procedures and/or misconceptions of students by proposing situations designed for this purpose to show the limits of old knowledge (respectively procedure) and to encourage the emergence of new knowledge (respectively procedure) (Brousseau, 2006; Chevallard, 1999).
- Variables V_{2t} aim to improve student's procedures and associated techniques by proposing tasks defined from the level of knowledge application and the adaptations needed (Robert, 2013). For the example in I: nature of coefficients, use of associative property, etc.

We now need to build a metric between the type of tasks and the tasks based on the epistemological reference.

Learning path model: We hypothesize that, for a given learning goal, the relationship between the learner's model (student's modes of activity defined *a priori*) and the epistemological reference relating to a given mathematical field (here algebra) makes it possible to select a relevant next exercise for the current learning path, by reasoning at two levels:

- What type of task should be proposed in relation to the learning goal? During a learning path, it may vary according to the distance between the student's algebraic skills and the targeted knowledge. The variables of type of task are involved here.
- What task should be proposed according study times? Depending on whether we want to develop or enrich procedures, the variables V1t or V2t are involved.

The feedback developed at the exercise level (see I), is not detailed here.

DISCUSSION AND PERSPECTIVES

We have illustrated the role of theoretical constructs and methodological approaches in order to build automatically learning paths by using the values of variables (type of task and task) to reduce the distance between the student's skills and targeted knowledge. The definition of all possible values of the variables makes it possible to explore the entire mathematical domain considered on the basis of epistemological and didactic study. We continue to work in collaboration with IT researchers to implement the learning paths in MindMath platform in algebra and plane geometry (Lesnes-Cuisiniez & al., 2019).

References

- Brousseau, G. (2006). *Theory of didactical situations in mathematics: Didactique des mathématiques, 1970–1990* (Vol. 19). Springer Science & Business Media
- Chaachoua, H. (2018). T4TEL un cadre de référence didactique pour la conception des E.I.A.H. In Pilet, Vendeira (Eds). *Pré-Actes du séminaire de didactique des Mathématiques*. pp. 5–22 (2018) .
- Chevallard, Y. (1999). L'analyse des pratiques enseignantes en théorie anthropologique du didactique. *Recherches en didactique des mathématiques*, 19(2), 221-266.
- Grugeon-Allys, B., Chenevotot-Quentin, F., Pilet, J., & Prévité, D. (2018). Online automated assessment and student learning: the Pepite project in elementary algebra. In L. Ball, P. Auteur, S. Ladel, H.-S. Siller, M. Tabach, & C. Vale (Eds.), *Uses of Technology in K-12 Mathematics Education: Tools, Topics and Trends* (pp. 245-266). New York: Springer.
- Kieran, C. (2007). Learning and teaching algebra at the middle school through college levels: Building meaning for symbols and their manipulation. *Second handbook of research on mathematics teaching and learning*, 2, 707-762.
- Lesnes-Cuisiniez, E., Grugeon-Allys, B. (2019). *Modèle d'exercices et parcours d'apprentissage prenant en compte le raisonnement de l'élève en mathématique au collège*. In Broisin, Sanchez, Yessad, Chenevotot (eds). *Actes de la 9e Conférence sur les EIAH*.
- Pilet, J. (2015). Réguler l'enseignement en algèbre élémentaire par des parcours d'enseignement différencié. *Recherches en didactique des mathématiques*, 35(3), 273-312.
- Robert, A. (2010). Une méthodologie pour analyser les activités (possibles) des élèves en classe. In : Vandebrouck, F. (ed.) *La classe de mathématiques : activités des élèves et pratiques des enseignants*, pp. 45–57. Octares
- Vandebrouck, F. (Ed.). (2013). *Mathematics classrooms: students' activities and teachers' practices*. Rotterdam: Sense Publishers.