From Laboratory to Authentic Contexts:

Two Studies of Pedagogical Reasoning Across Four Levels of Expertise

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Abstract

A cognitive model of how teachers plan instruction was validated in laboratory settings but remained to be tested empirically in authentic situations. The objective of this work is to describe and compare pedagogical reasoning in laboratory and authentic contexts and across expertise levels. The "state-driven hypothesis" and the "knowledge-driven hypothesis" were used in two studies to show how pedagogical reasoning was performed by novices and experts in laboratory (n=18) and in authentic context (n=14). Globally, the results show (1) similarities and differences in how pedagogical reasoning unfolds in laboratory and authentic contexts and (2) how domain knowledge influences only some aspects of this process. The work presented lays the foundations for the fine-grained study of how domain knowledge determines problem-solving in pedagogical-reasoning.

Keywords: Pedagogical reasoning, Expertise, Teacher cognition, Teacher knowledge

1. Introduction

Teacher planning has been identified as a crucial activity for innovation in teaching and for teacher development (Hasweh, 2005; McCutcheon & Milner, 2002). It is mainly during planning that teachers reflect on their teaching, make adjustments, and consider implementing innovative methods and tools. In order to further foster planning skills in student teachers, a model that shows how teachers think during planning was needed. Indeed, recent conceptualizations of instructional systems design in professional domains hinge on specifications of global and authentic tasks, including procedures and knowledge associated to them (van Merriënboer & Boot, 2009). Such a view represents a potentially fruitful bridge between expertise research and educational psychology. Among other things, this bridge motivates the use of cognitive task analysis and expert-novice research to inform pedagogical design. Whereas cognitive task analysis is essential in specifying what is to be learned for competent performance in a domain (Schraagen, 2009), expert-novice research typically unveils "a trajectory to expertise" (Lajoie, 2003). As a precursor to the design of a technology-enhanced learning environment for teacher planning, a model of pedagogical reasoning has been developed from a cognitive perspective. It was tested with samples of teachers across a broad range of expertise levels, in individual and collaborative performance settings. These studies were conducted in laboratory settings over a relatively short period of time. Results have shown on the one hand how pedagogical reasoning unfolds and, on the other hand, on which domain knowledge this process hinges when the task is to elaborate learning activities on the basis of the description of a single student with learning difficulties.

The model was validated in laboratory settings but remained to be tested empirically in authentic situations. The need for translational research, which relates results from laboratory and naturally-occurring performance, is increasingly being recognized for expertise research to have a consequent impact on theories and practices regarding skill acquisition (Ericsson & Williams, 2007). The objective of this study is to describe the pedagogical-reasoning process as it unfolds in authentic teaching situations over an extended period of time and across expertise levels. A characterization of how teachers think during pedagogical planning in realistic settings is required in order to use the postulated pedagogical-reasoning model in the study of how teaching skills develop and how these skills can be scaffolded in school settings through a technology-enhanced learning environment.

2. Theoretical Framework

The term pedagogical reasoning has been used at least since the mid-1980's to describe, in various ways, how teachers make decisions about their teaching. Shulman's (1987) model accounted for aspects of teaching practice and specified a series of actions centered around pedagogical content knowledge (comprehension of subject knowledge, transformation into learning objects and instruction) and reflective practice (evaluation of students' learning and teacher's performance, reflection, and new comprehensions). Starkey (2010) recently adapted this model to the "digital age" in a connectivist view. Indeed, the consideration of the potential of connections made possible by technology for learning during the transformation of subject knowledge into learning objects is the major addition to the model. Pedagogical reasoning was the central idea of Young and Bird's (2010) study of the development of teaching expertise as a result of pre-service training. In their view, pedagogical reasoning is constituted of the acquisition of curricular knowledge, the planning and delivering of instruction, and the preparation of assessment. It is worth mentioning that these authors have created a validated procedure for the assessment of pedagogical reasoning that seems compatible with the finer-grained model of the present study. Finally, pedagogic reasoning was used in a different context by Legaspi, Sison, Fukui and Numao (2008) to refer to the computations of an intelligent tutoring system that produce a dynamic model of the learner to which the system adapts. In this section, the model of pedagogical reasoning tested in this study is presented and then situated in a more general framework of cognitive functioning. The results from previous studies are then summarized, followed by the research questions and hypotheses.

2.1 A model of pedagogical-reasoning

Teacher planning was theorized as pedagogical reasoning within a cognitive perspective, under the assumption that this emphasis on cognition would provide insights regarding the educational psychology of teacher training. General concepts associated with cognitive functioning such as comprehension (Kintsch, 1998), reasoning (Johnson-Laird, 2005), planning (Leinhardt & Greeno, 1986) and problem solving (Hatano & Inagaki, 2000; Novick & Bassok, 2005) were contextualized to the task of teacher planning, as shown in Figure 1.

<Figures 1 & 2 about here>

Pedagogical reasoning is described as a set of components in which sub-components are nested. The components are articulated by a general problem-solving mechanism. These components represent the cognitive activities associated with (1) building an understanding of the student(s) for which the learning activity is intended, (2) making a diagnosis of the student' learning difficulties, and (3) planning appropriate instruction. Building an understanding of the student(s) involves comprehension processes, in which the information available is supplemented by pertinent domain knowledge possessed by the teacher. Question-asking supplements the interaction between information and knowledge by signaling the need for further information when appropriate. The diagnosis is realized through reasoning, in which hypotheses are formulated and tested using inferences. The planning of instruction consists of setting instructional goals, specifying actions likely to fulfill these goals and their effects, and the constraints surrounding the enactment of these actions. Problem-solving processes are superposed to these three components and act as a coordination mechanism. These processes include goal setting, planning actions and testing the conditions for their enactment, performance monitoring, evaluation and correction of mistakes.

Regarding the temporal sequencing of pedagogical-reasoning activities, a specific order can be postulated. Expected paths include the transitions between regulation states and pedagogical-reasoning actions. Indeed, any regulated activity should be preceded by adequate preparation, be realized carefully, and then be followed by appropriate evaluation of its results. This holds for all the levels of the decomposition of the pedagogical-reasoning task, but a detailed examination of the sub-components is beyond the scope of this paper. In addition, the pedagogical-reasoning process is hypothesized globally to begin with building an understanding of the student(s), followed by the elaboration of a diagnosis, and to conclude by the planning of the pedagogical intervention. That is, a suitable result or output of a preceding component is a necessary condition for a subsequent component to be realized successfully. Therefore, a pedagogical-reasoning episode should begin by an examination of the current situation, and should end when reputedly effective instruction (in the eye of the teacher) has been planned for that specific context. A new pedagogical-reasoning episode will eventually take place following a change in the situation since the last episode, attributable or not to the realization of the teaching activities that were previously planned.

2.2 A general framework of cognitive functioning

In relationship with the model presented, two general ideas about cognition can be explored. Although widely accepted as theories, these ideas are described in the present context as hypotheses, to emphasize that the studies presented will explore how they are instantiated empirically within the model. A first hypothesis is that cognition unfolds

as a series of discrete states and that a given state is dependent on the preceding states. A second hypothesis is that appropriate knowledge has an influence on how cognition unfolds.

The state-driven hypothesis originates from studies of the cognitive architecture. Newell (1990) describes how controlled behavior, including cognitive behavior, is subjected to serial processing whereas automatic functions are realized by parallel processing. He then evokes temporal constraints stemming from the necessary operations needed to perform a given activity (i.e. achieve a certain state). Massive amounts of behavioral data from the information-processing tradition in cognitive science provided support for this fundamental property of cognition (Anderson, 2002). Recent methodological advances are now producing new empirical evidence of state-driven cognition at the neural level. Electroencephalography (EEG) (see Campbell, 2011) and functional neuro-imagery (IRMf) studies (Anderson, Carter, Fincham, Qin, Ravizza, & Rosenberg-Lee, 2008; Anderson, Albert, & Fincham, 2005) are beginning to illustrate how brain regions sequentially activate during the performance of tasks radically more complex than those traditionally used with this machinery.

The knowledge-driven hypothesis derives from expertise research. This body of work shows how domain knowledge influences cognitive behavior. Generating the best solution to a problem, detecting important features in a problem or situation, developing a rich representation of a problem, monitoring performance, choosing better strategies, and using minimal cognitive effort constitute the various ways in which knowledge favorably impacts cognitive functioning (Chi, 2006). Expertise research should examine "naturally-occurring activities" that represent expertise in a given domain (Ericsson, 2006).

The serialism of controlled cognitive behavior represented by the state-driven hypothesis coupled with the impact of knowledge on cognitive functioning underlying the knowledge-driven hypothesis constitute an interesting interaction to study, and the work presented in this text could contribute to this endeavor.

2.3 Results from earlier studies

The main goal of the studies to date was to validate the model postulated from the theory on the basis of the prevalence of the categories and their sequencing. Experiments were designed to describe pedagogical reasoning in remedial reading instruction along a continuum of expertise from novices to experts. The expertise levels were identical in all studies. They were constituted of second-year student teachers (of a four-year teacher education program), fourth-year student teachers, teachers in special education with five years of experience, and teachers who had a graduate degree in the field. In addition, pedagogical reasoning was studied in individual and collaborative contexts under the assumption that the same categories can be used to characterize the performance of the task by individuals and teams (Tschan, 2002). Finally, the costs and benefits of individual and group performance were examined.

The study of individual pedagogical reasoning has shown that there were no differences in the prevalence of problem-solving processes attributable to expertise. Performing actions was the most frequent category (39%), followed by interpreting the current state of the pedagogical-reasoning process (30%) and planning pedagogical-reasoning actions (16%). Each of the remaining categories represented less than five percent of the occurrences. In contrast, differences were observed at the level of actions. As expertise increases, making a diagnosis represents a higher proportion of events while the planning of interventions is less prevalent. The sequencing of pedagogical reasoning was found to be idiosyncratic for each level of expertise. The absence of clear patterns in the data was attributed to the analytic strategy. Indeed, the original report described the process by insisting on the problem-solving framework in which pedagogical-reasoning activities are embedded. The seven categories that characterized problem solving led to a high number of paths with the pedagogical-reasoning categories, which were not fully interpretable. In subsequent analyses emphasizing the sequential structure of pedagogical reasoning (Author, submitted), problem-solving was reconceptualized in a more compact action regulation framework (Tschan, 2002). With its three subsequent phases of preparation for action, enactment of action and evaluation of the results, this framework can be used to collapse the six problem-solving categories into three (Author, submitted). In order to enable comparisons between the laboratory results and the results of the present study, a new analysis of the data from this earlier study is presented in this paper.

The results of the study of collaborative pedagogical reasoning replicate to a great extent the results about the prevalence described in the context of individual pedagogical reasoning. This study indicates that expertise is not related to the prevalence of problem-solving processes. The performance of actions was again the most prevalent category (38%), while the interpretation of the current state of the process and the planning of actions represented 30 percent and 13 percent of the occurrences. With the exception of the test of conditions required for the enactment of pedagogical-reasoning actions (10%), each of the remaining categories did not contain more than 5 percent of the occurrences. At the level of actions, expertise was shown again to be related to a strong tendency to engage more often in making a diagnosis and less often in planning the intervention. Sequential dependency was statistically established for all levels of expertise except the practicing teachers. Globally, planning goals was followed by planning actions (+).

Other significant transitions were: Test condition-Comprehend (+), Diagnose-Comprehend (+), Test Conditions-Interpret State (-), Correct-InterpretState (+) and Diagnose-PlanIntervention (-). For the second-year student teachers, two paths were excitatory (i.e. more frequent than expected statistically): PlanGoal-PlanAction(+) and Diagnose-Comprehend(+). In the case of fourth-year student teachers, four transitions occurred significantly more often than chance level: PlanAction-Comprehend(+), Reason-Comprehend(+), Reason-Correct(+), Evaluate-PlanIntervention (+). Experts' pedagogical reasoning was globally more sequentially structured than the other expertise levels. Reflecting the global statistic, six excitatory paths were observed: PlanGoal-PlanAction(+), PlanAction-InterpretState(+), TestConditions-InterpretState(+), Correct-InterpretState(+), PlanAction-Comprehend(+), Comprehend-Reason(+). InterpretState was thus a potent point attractor in the experts' pedagogical-reasoning phase space. It can be concluded from this study that aspects of task performance are similar across individual and collaborative situations.

The study of the costs and benefits of individual and collaborative performance in pedagogical reasoning has shown that dyads were more efficient than individuals (Author, submitted). That is, dyads were more inclined than individuals to follow a prescribed path in action regulation that proceeds from preparation, execution of actions, and evaluation of the results (Lipshitz & Bar-Ilan, 1996). With respect to the quality of the instructional intervention produced at the completion of the pedagogical-reasoning process, no gains attributable to collaboration were observed. The quality of the intervention was related to the expertise level. The results of this study need to be complemented by an examination of how each of the components of pedagogical reasoning is regulated across expertise levels.

To sum up, these studies provided a coherent portrait of the relative importance of the various pedagogical-reasoning activities as realized in a laboratory setting. Regarding the sequential aspect of the process, results have shown that the use of sequential analysis with a substantial amount of categories can lead to hardly interpretable chronological patterns and that complementary analyses emphasizing different aspects of the process are needed.

2.4 Research questions and hypotheses

In order to make comparisons with the previous results, the research questions are identical to those used in earlier studies. Based on Mercier, Girard, Brodeur, and Laplante, (2010), the four following questions were answered in this study: (1) what is the relative prevalence of the pedagogical-reasoning processes, (2) does this relative prevalence vary across expertise levels, (3) what is the typical sequencing of the pedagogical-reasoning processes, and (4) does this sequencing vary across expertise levels? On the basis of the previous considerations, the following hypotheses were tested in answering the questions: (1) the prevalence of the pedagogical-reasoning activities is the same across laboratory and authentic context, (2) the effect of expertise on the prevalence will be present in both contexts: as was shown in laboratory data, making a diagnosis represents a higher proportion of events while the planning of interventions is less prevalent in authentic context as expertise increases, (3) transitions representing ideal cycles of action regulation are excitatory, whereas paths not representing this cycle are inhibitory, and (4) as expertise increases, more appropriately excitatory transitions and more appropriately inhibitory transitions will be observed.

3. Study 1: In the Laboratory

This section presents a new analysis of the data from the study of individual pedagogical reasoning. Questions 3 and 4 were reexamined in the context of an action regulation framework. Complete results for the first two questions can be found in Mercier, Girard, Brodeur, and Laplante (2010).

3.1 Method

This section summarizes the parameters of the original study.

3.1.1 Participants

Eighteen women participated in this study. Six were student-teachers completing the first half of a four-year teacher education program in special education, six were student-teachers completing the fourth year of the same program, two were practicing teachers in the field of special education, and four were experts who had completed a graduate degree in remedial reading instruction. For simplicity of language, the four expertise levels are identified as 2Y (second-year), 4Y (fourth-year), PT (practicing teachers) and ET (expert teachers) throughout the text.

3.1.2 Task and setting

Participants were asked to plan remedial reading instruction for a student described in a detailed case study. To do so, participants were met individually by a research assistant in a small room at the university. A computer was used by the participant to read about the case and to write the lesson plan. The laboratory was equipped with a camera to record the computer screen and the speech of the participant. Indeed, she was instructed to think out loud (see Ericsson & Fox (2011) for details). The research assistant was present during the two hours of the experimentation to manipulate the

camera and remind the participant to verbalize her thinking each time nothing was said for five seconds.

3.1.3 Data preparation

Data were transcribed and then coded with the categories of the pedagogical-reasoning model. The lesson plans produced during the experiment were not used in the present analysis.

3.1.4 Plan of analysis

Categories related to problem solving were collapsed into the categories associated with action regulation. Sequential analysis was then used to answer questions 3 and question 4. Sequential analysis is a statistical method to investigate the sequential dependency between recurring events constituting a process. It is a set of tools to conceptualize, build and examine contingency tables representing how a system functions through a series of potential steps. The sequential dependency of an event can be characterized as the relative probability of states preceding it, thus causing the event to occur from a temporal point of view. Prior statistical analysis, the contingency table has to be created by computing, for each state in a process and for each time it occurred, the state preceding it. Sequential dependency is present when the conditional probabilities are significantly different from the unconditional probabilities. Sequential dependency can be excitatory or inhibitory, when the probability of a transition is higher or lower than expected, respectively. Unlike common inferential statistical analysis based on the assumption of independence of observations, this method investigates this dependency. Sequential analysis can include comparisons from factors in a design, and is not affected by unequal sample size. Question 3 was answered without considering the expertise level, whereas question 4 included this factor. As prescribed by Gottman and Roy (1990), the issue of the order of the Markov chain was examined prior to the analysis related to the research questions regarding the sequence of the process. The order is the structure of dependency among events. A given consequent could be dependent on no previous antecedent, the first antecedent, the first two antecedents, and so on. For parsimony of the model, the exploration of the order starts with one antecedent and ends when dependency is detected. A significant statistic is wanted. A significant chi-square for a given lag indicates that there is sequential dependency in the data. The analysis, based notably on dynamic systems theory, rests on the notions of attractors and repellers in a phase space (Arrow, McGrath, & Berdahl, 2000). A phase space represents the array of states that a system occupies in a given period of time. Within the phase space, attractors represent states the system is in or tends toward more frequently whereas repellents represent states that the system tends to avoid. A point attractor is a single state, whereas a recurring cycle is a periodic attractor. Finally, it should be noted that the inferential statistics describe the properties of the database and should not be interpreted as indications of generalizability of the results since the sample is not parametric.

3.2 Results

3.2.1 Question 3

The test of the order of the Markov chain indicates a dependency of a current state on the immediately preceding state (χ^2_{11} = 1200.77, p< .0001). This means that for the sample of this study, the immediate subsequent pedagogical-reasoning activity that a participant will engage in is predicted by the current activity. These predictions are described in the following figure. Continuous lines represent excitatory paths whereas dotted lines represent inhibitory paths. An excitatory path denotes a transition occurring significantly more often than expected, and on the contrary, an inhibitory path signifies a transition statistically less frequent than expected. The g-square, a variant of the chi-square, is used in detecting excitatory and inhibitory paths. The threshold for the alpha level was set to the conventional .05.

< Figure 3 about here>

Irrespective of the expertise level, the sequential nature of pedagogical reasoning reveals that all transitions between states except one are either excitatory or inhibitory, as displayed in Figure 3. The only path not statistically different from chance is Preparation_Evaluation. All paths between preparation and planning and between evaluation and planning are excitatory. The path between evaluation and preparation is also excitatory. All other paths are inhibitory. Comprehension and diagnosis constitute a periodic attractor in which these two states occur recurrently, is relative isolation from the other states. Planning is a point attractor for preparation and evaluation. Globally, these patterns depict pedagogical reasoning as a modular activity in which Comprehension and Diagnosis interact in isolation, followed by Planning, which involves Preparation and Evaluation.

3.2.2 Question 4

Before examining the sequential properties of pedagogical reasoning for each level of expertise, statistical sequential dependency must be established for each level. A non-significant chi-square indicates the absence of sequential dependency (i.e. the process is unstructured and its constituting events occur randomly). Thus, the absence of sequential

dependency for one expertise level prevents any further analysis for that sub-sample. The analysis would have to be performed with the remaining expertise level(s). Table 1 presents the statistics for the test of order.

< Table 1 about here>

Sequential first-order dependency is observed in all cases, and it was determined that the following analyses would be conducted with the first-order model. For clarity of presentation, the results are presented in a table, but the information is of the same nature as in Figure 3.

< Table 2 about here> & <Figure 3 about here>

Most transitions in Table 2 are either excitatory or inhibitory. Seven of those transitions are uniformly statistically significant across expertise level. Three are uniformly excitatory (Preparation - Intervention (+), Comprehension - Diagnosis (+), Evaluation-Intervention (+)) whereas four are uniformly inhibitory (Preparation - Diagnosis (-), Comprehension-Intervention (-), Comprehension-Evaluation(-), Diagnosis-Intervention(-)) and do not differ according to expertise. Ten of the remaining excitatory or inhibitory transitions did not reach statistical significance for one or two expertise levels. It should be noted however that no path was found to be inhibitory for some expertise levels and excitatory for others. Finally, the path from preparation to evaluation is inhibitory for experts only and the path from evaluation to preparation is excitatory, again only in the case of experts. They are thus non-significant for the three other expertise levels. Globally, seven transitions are not affected by expertise, while 12 are. The total number of appropriately excitatory of inhibitory paths is 4, 8, 6, and 10 for 2Y, 4Y, PT and ET respectively. The results of this study will be discussed in conjunction with the findings of the next study.

4. Study 2: At the School

4.1 Method

4.1.1 Participants

The sample was constituted of fourteen participants. Three were student teachers who had completed the second year of a four-year teacher education program in special education. Three were student teachers in their final year of the same program. Four were practicing teachers with five years of experience in the field of special education. Finally, four were practicing teachers who had a graduate degree in remedial reading instruction. Their participation was voluntary and the students did not receive any course credit. Participants were paid inclusively for the three weeks they devoted to the study.

4.1.2 Task and setting

The data collection procedure was designed to capture pedagogical reasoning as it was realized by the participants in an authentic teaching setting during a period of three weeks. Student teachers participated in the study during the annual teaching practicum prescribed by the program. Data from the practicing teachers were collected in the weeks following their agreement to participate, during the regular school year. In the days preceding the data collection period for a participant, she was met individually at our laboratory by a research assistant for an orientation session. Each participant was given a recent portable computer from a fleet of 35 especially configured to record the screen and ambient sound whenever it was turned on. Any file displayed and modified in the word processor was also recorded every minute as a new, time-stamped file. The memory of the computer allowed hundreds of hours of recording, more than enough for the entire 21 days. Participants were instructed to use the computer whenever they planned instruction in reading during the three weeks period. In addition, they were asked to talk out loud in front of the computer, which was also configured to display a popup window reminding the participant to verbalize her thinking each time no speech was recorded for five seconds to augment the completeness of the think-aloud protocols collected. Participants were met again shortly after the data collection for a debriefing session, return of the computer, and retribution.

4.1.3 Data preparation

Data from each computer issued were transferred to the LabMECAS secure servers for archiving and further preparation for analysis. Files associated with the use of the word processor were archived unmodified. The hundreds of hours of recording were checked and any problem of synchronization between sound and image was resolved. The material was then viewed entirely and each film was characterized by a brief description. Specific pedagogical-reasoning episodes were finally randomly selected for data analysis to constitute a total of two hours of think-aloud recording for each participant. These 18 hours of material were then transcribed and coded using the categories of the pedagogical-reasoning model. Table 3 presents the operational definitions of the categories.

< Table 3 about here>

4.1.4 Plan of analysis

Questions 1 and 2 were answered by compiling time-budget information for each step. Question 3 and 4 were answered by computing transitional probabilities between steps. For these questions, data analysis focuses on excitatory and inhibitory transitions. For both set of questions, results for the whole sample are presented, followed by results associated with each level of expertise.

4.2 Results

4.2.1 Preliminary description of the dataset

The database submitted to analysis consisted of a total of 160 episodes of pedagogical reasoning. The mean length of a little more than a hundred cognitive states (of various length since they can be decomposed into sub-components) varies greatly (*SD*=113.25). The selection of these episodes has led to shorter episodes for 4Y and PT while 2Y and ET were longer. The typical episode for each level expertise level is difficult to characterize on this basis because of the substantial standard deviations: episodes of different length were selected for the corpus, as shown in Table 4.

< Table 4 about here>

4.2.2 Question 1

The relative prevalence of the pedagogical-reasoning regulation processes in authentic context is presented in table 5.

< Table 5 about here>

The prevalence of the categories is not equal (χ^2_2= 971.78, p< .0001). The execution of pedagogical-reasoning actions represents 64% of the occurrences whereas the preparation for those actions and the evaluation of the results represent respectively 29% and 7% of the occurrences. In the case of the pedagogical-reasoning actions, the prevalence is also not equal (χ^2_2= 495.02, p< .0001). The participants engaged more often in planning the intervention (59%). They engaged in comprehending the situation 36% of the time. Finally, diagnosing a student's difficulty represented 5% of the occurrences.

4.2.3 Question 2

The second question examined if the relative prevalence among regulation and pedagogical-reasoning activities varies across expertise levels. The descriptive statistics are presented in Table 6.

< Table 6 about here>

The prevalence of the regulation processes varies with expertise (χ^2_6= 72.79, p< .0001). The preparation for action and the evaluation of the results tend to be less frequent as the expertise augments. Inversely, the execution of pedagogical-reasoning actions is relatively more prevalent as the expertise increases, the higher proportion of 73% being observed in PT.

The expertise level is associated with differences in the relative prevalence of pedagogical-reasoning actions (χ^2_6= 158.83, p< .0001). The comprehension of the situation is less frequent in second-year students and represents between 36% and 45% of the occurrences for the other expertise levels. The diagnostic activity occurs more often as expertise increases, counterbalanced by a corresponding decrease in the prevalence of the planning of interventions. The hypothesis is therefore accepted.

4.2.4 Question 3

The test of order shows sequential dependency for the whole sample (χ^2_{11}=175.26, p<.01). For the participants in this study, a given performed pedagogical-reasoning state has an effect on the relative probability of all candidate states in the phase space to be the next state to be performed. To examine in more details this global finding, the specific transitions affected in this manner are presented in Figure 4.

<Figure 4 about here>

The sequential analysis of the pooled data across expertise levels reveals two main characteristics of the pedagogical-reasoning process, as shown in Figure 4. On the one hand, comprehension and diagnosis operate in relative isolation from the other states. They constitute a periodic attractor repulsing the elaboration of the intervention and occurring without the hypothesized preparation and evaluation steps that should constitute a necessary condition for a shift in activity. On the other hand, the elaboration of the intervention is realized in conjunction with the two regulative activities (preparation and evaluation). Regarding the regulation of the process, the transition between preparation and evaluation is inhibitory and the transition between evaluation and preparation did not reach statistical significance.

4.2.5 Question 4

The results of the test of order for each level of expertise are presented in Table 7.

< Table 7 about here>

The test of the order of the Markov chain reveals first-order dependency for 4Y, PT and ET. However, first order dependency was not observed for 2Y (χ^2_{11}= 18.6, p< .068). Consequently, the following interpretation of the results does not include 2Y.

< Table 8 about here>

The sequential analysis of pedagogical reasoning as enacted by the participants of various expertise levels reveals that most transitions can be characterized uniformly across expertise levels. The details are presented in Table 8. Ten paths are not significant. The Comprehension-Preparation transition is inhibitory, whereas the Diagnosis-Comprehension path is excitatory. Intricately, the five paths that reached significance for two of the three expertise levels do not implicate adjacent expertise levels and thus concern the 4Y and ET. One transition, Preparation-Comprehension, was found to be inhibitory for the experts only. The total number of appropriately excitatory of inhibitory paths is 1 for PT, and 4 for 4Y and ET.

5. General Discussion

5.1 Question 1

The hypothesis tested in relationship with question 1 is that the prevalence of the pedagogical-reasoning activities is the same across laboratory and authentic context. Irrespective of expertise, pedagogical reasoning in authentic setting is mostly constituted of the execution of actions. The remaining third of the cognitive activities is devoted to the regulation of those actions, mostly for preparation and almost never for evaluation. By stressing the importance of both evaluation and preparation during transitions between actions during the performance of a task, the action regulation framework would predict equal occurrences of preparation and evaluation. From this point of view, this quantitative deficit in evaluation steps suggests that the pedagogical-reasoning task is not optimally regulated. However, Lipshitz and Bar-Ilan (1996) asserted that adequate diagnosis during monitoring and the compatibility of diagnosis and action were related to successful problem solving, and could counterbalance departures from ideal cycles of action regulation. Similarly, Mercier, Girard, Brodeur, and Laplante (2010) found that action regulation represented one third of the cognitive activities. The ratio between preparation and evaluation activities is about two preparation activities for one evaluation occurrence. Hypothesis 1 is therefore confirmed at the level of the control processes.

At the level of actions, there are striking differences between laboratory and authentic results. Authentic pedagogical reasoning consists mainly of planning interventions (59%) whereas diagnosis is almost absent (5%). In the laboratory, diagnosis represented three to six times that amount, with a corresponding decrease in the prevalence of lesson planning. Assuming that the detailed characterization of the pupils through diagnosis takes time - as shown in the laboratory by Mercier, Girard, Brodeur, and Laplante (2010) - that is not reflected in the extremely low frequency observed, this emphasis on lesson plans seems to denote, on the part of the teachers, an underestimation of the importance of student diagnosis for efficient teaching or their incapacity to do this assessment. This leads to the potentially generic nature of the interventions implemented in schools by special education student teachers and teachers. Hypothesis 1 is therefore rejected at the level of the pedagogical actions.

5.2 Question 2

The hypothesis tested was that the effect of expertise on the prevalence will be present in both contexts. Making a diagnosis represents a higher proportion of events while the planning of interventions is less prevalent in authentic context as expertise increases. The prevalence of the regulation processes varies with expertise. This finding does not replicate the laboratory study, in which the control process of pedagogical reasoning was analyzed using the problem-solving categories and was found to be equally prevalent across expertise levels. Hypothesis 2 is therefore rejected at the level of the control processes. Two lines of thought can explain the propensity, associated with an increase in expertise, to engage less often in preparation and evaluation activities and more often in the execution of pedagogical-reasoning actions. Pertinent domain knowledge has an effect on the executive aspect of a problem-solving task (Hatano & Inagaki, 2000). Notably, this knowledge facilitates the identification of solution strategies, which may lead to compiled plans of actions. With repeated use, those plans of action, as complex as they can be, get automatized and in consequence can be presumed to require less executive control. Another explanation involves the quality of regulation. If the idea that expertise is associated with better action regulation is held to be true, then a qualitative view of regulation has to be examined. Presumed qualitative executive control is inversely related with the notion of

prevalence, originating from a quantitative point of view, in which more often is better. It could be hypothesized that a fruitful high-level regulation is better and that more frequent, low-level regulation is a relatively undesirable consequence or compensation mechanism for the impossibility of this high-level control. The implication of compiled plans of actions evoked previously also goes in the same direction, since the gain of using those plans of actions is the decrease in the need for regulation during their enactment.

The comprehension of the situation is less frequent in second-year students and represents between 36% and 45% of the occurrences for the other expertise levels. This reflects the novices' propensity to plan generic interventions irrespective of the current teaching context. This does not mean however than these interventions are inadequate. The novices in this study can be portrayed as choosing from a pool of interventions that they are currently constructing as a result of teaching experience and university courses in pedagogy. This is not to say however that those interventions would not gain in efficiency by being contingent on the students' needs (Wood, Bruner & Ross, 1976). This contingency is probably the incentive sought for by the more expert participants when they decided to put more effort in building an adequate representation of the situation. Whether or not better teaching activities result from this is a question to be examined in an analysis of the lesson plans that were collected in the present studies.

The expertise level is associated with differences in the relative prevalence of pedagogical-reasoning actions. The diagnostic activity occurs more often as expertise increases, counterbalanced by a corresponding decrease in the prevalence of the planning of interventions. This finding replicates laboratory results and hypothesis 2 is therefore confirmed. Moreover, the magnitude of this relationship is intensified in authentic settings, in which experts' diagnostic process represents twice as much occurrence as PT and ten times the frequency that novices devote to this process. In comparison, Mercier, Girard, Brodeur, and Laplante (2010) found a twofold increase in experts relative to novices.

5.3 Question 3

The hypothesis was that transitions representing ideal cycles of action regulation are excitatory, whereas paths not representing this cycle are inhibitory. First-order sequential dependency was found both in the laboratory and authentic studies. This dependency of a current cognitive state on the immediately preceding state that was found indicates that pedagogical reasoning is subject to some form of executive control, either conceptualized as action regulation or problem-solving (Author et al., 2010a). This executive control operates on a very short history of the performance - the preceding state only - but the results do not rule out a possible gain in considering a longer history (the two preceding states, and so on). These findings corroborate the classic idea that cognition is state-determined (Newell, 1990), which originated from the study of problem solving in knowledge-lean tasks, and contribute to extend it to knowledge-intensive tasks. This demonstration, along with the same discovery in the study of collaborative pedagogical reasoning (Mercier, Brodeur,, Laplante, & Girard, 2010) has implications for the multi-level study of pedagogical reasoning either from a neuroscience or social cognitive science point of view. From a social cognitive science perspective, it means that the cognitive states of individuals working in teams or groups can be directly related to the "social-cognitive" states (see Sun, 2006 and Greene, 2011) of the team or group performing a problem-solving task. In the same manner, a neuroscientific exploration of the mapping between the cognitive states established in the pedagogical-reasoning model and the neurological states on which these cognitive states hinge as they unfold in time is within conceptual and methodological grasp. Recent advances in the instrumentation are offering techniques with sufficient temporal resolution, and improvements in spacial resolution by either data acquisition or data analysis techniques are being reported (Harmon-Jones & Harmon-Jones, 2011). While fMRI has still a tremendous advantage in spacial resolution for both structural and functional brain imagery at the expense of subject's mobility and other constraints, EEG can be seen as the technique of choice for the near future with the availability of relatively unobtrusive wireless headsets. The mapping between neurological and cognitive states that will be developed over time with enable the study of the correspondences between cognitive and social-cognitive processes in dramatically novel ways: social cognitive data will not be constrained to an integrated conversation stream that says little about the cognitive states of the participants but will include the parallel neurological trace of each participant from which their respective cognitive state will be determined.

Irrespective of the expertise level, the sequential nature of pedagogical reasoning reveals that all transitions between states except one are either excitatory or inhibitory. Hypothesis 3 is therefore accepted in the laboratory study. In the authentic study, many paths did not reach statistical significance. Consequently, hypothesis 3 is rejected. At the level of specific paths, laboratory and authentic pedagogical reasoning present similarities in their sequential structure. More transitions were found to be excitatory or inhibitory in the laboratory study, suggesting that authentic pedagogical reasoning is less orderly structured. Nevertheless, the significant paths found in authentic data were all significant and of the same valence as in the laboratory data, with the exception of Preparation-Evaluation(-) which did not reach

significance in the laboratory data. Evaluation-Intervention(+) was not significant in the authentic performance as were many inhibitory transitions. If it can be asserted that teachers' intentions and the means to realize them can be transposed into the relationships between regulation activities and pedagogical-reasoning component actions, then pedagogical reasoning seems to be driven exclusively by instructional planning operations and the Comprehension and Diagnostic components act as "client processes". Taking into account the expertise level, this conclusion holds.

5.4 Question 4

The hypothesis associated with question 4 is that as expertise increases, more appropriately excitatory transitions and more appropriately inhibitory transitions will be observed. As shown by the test of order, pedagogical-reasoning cognition is not only state-determined, its regulation during the performance of a pedagogical-reasoning task is facilitated if adequate domain knowledge is available. The performance of 2Y in authentic settings even suggests that regulation is possible only in the presence of sufficient domain knowledge. This represents partial support for Hypothesis 4. At the level of specific transitions, data from both studies leave the question unanswered since neither consistency nor progression across expertise levels could be observed in the number of appropriate transitions.

In both studies, the differences related to expertise regarding the specific transitions raise many questions. The many paths that were uniformly significant (excitatory or inhibitory) or non-significant (50% of total transitions) do not permit to locate the differences associated with expertise that were found globally using the test of order. For the other paths, 9 were found for non-adjacent expertise levels. In the case of the paths for which only one expertise level was different from the others, 8 were extreme whereas 3 where 4Y or PT. Following the knowledge-driven hypothesis, theories of expertise would predict a tendency for adjacent levels to perform similarly. Likewise, exceptions should be found in extremes only.

6. Conclusion

The implications of the results for the design of a technology-enhanced learning environment are presented. They are followed by indications for future studies.

The "state-driven hypothesis" and the "knowledge-driven hypothesis" were the basis of the study of how pedagogical reasoning was performed from a cognitive point of view by novices and experts in laboratory and in authentic context. This study contributes to the design of a technology-enhanced learning environment by specifying what is to be learned in order to become expert in planning instruction. It also suggests that the pedagogical-reasoning model is an adequate depiction of teacher planning in real-life settings. It can therefore be used in conjunction with recent (professional) learning models hinging on global and authentic tasks. It is now possible to proceed with the extraction of procedure frames for the procedural guidance and of the mental models for the specification of the domain knowledge associated with competent pedagogical reasoning. These studies have shown that comprehension and diagnosis are interactive in pedagogical reasoning, whereas the planning of the intervention is completely modular. Further examination of the lower-level processes constituting these activities should investigate the nature of the transitions between comprehension and reasoning while instructional planning can be analyzed separately.

Results of Question 1 suggest that learners would benefit from guidance in regulation with a particular emphasis on evaluation. Specific prompts will be included to this end. They will be triggered at the outset and completion of sub-tasks. The outcomes of Question 2 imply that novices would benefit from an insistence on an adequate and sufficient comprehension of the situation prior to the actual planning of learning activities. The learning environment will include sub-tasks and information requiring and helping learners to develop this ability to attend to important information in a teaching situation and conceptualize a problem prior to its solution. In addition, the technology-enhanced learning environment should provide extensive procedural guidance based on the structure of the pedagogical-reasoning task. A very detailed interactive schematization of the pedagogical-reasoning procedure should be provided to novices, with each component accompanied by pertinent domain knowledge. As they progress, learners will eventually have the option of hiding low-level procedural elements. Domain knowledge will also progressively "fade" in response to the learner's mastery of the content as determined by results from automated tests. This schematization will also structure the content of the description of the learning activities planned by learners: they will be instructed to provide information for each component of the procedure. In showing that comprehension/diagnosis and planning are modular, the results associated with Question 3 suggest that abilities for diagnosis can be taught and scaffolded separately from planning skills. The technology-enhanced learning environment that will be developed will therefore include sub-tasks exercises targeted at improving on the one hand the comprehension of a learning situation and the diagnosis of students' difficulties and on the other hand the planning of instruction. In addition, the regulation predominantly observed in relation with planning strongly indicates that instructional planning is the backbone of authentic pedagogical reasoning. Consequently, the regulation should be organized around this process. The learning environment will be structured around a flowchart representing planning as the main activity, with comprehension of the situation and diagnosis as crucial satellite processes.

Question 4 illustrates that pertinent knowledge facilitates pedagogical reasoning. It follows that pertinent information should be provided to novices. However, the acquisition of this knowledge represents an additional burden on cognitive resources (Sweller, 1988) in the context of learning in problem-solving situations. The learning material should therefore be fragmented and presented "just-in-time" and incrementally, as prescribed by studies of tutoring (Chi, Siler, & Jeong, 2004).

A quantitative description of action regulation has led to the conclusions that (1) pedagogical reasoning was better regulated in laboratory in comparison to more ecologically valid situations and (2) that this regulation augments with expertise. Analytic strategies complementary to those used in the present studies should be used to shed light on the issues that were raised previously. Qualitative analysis should be superimposed to the sequential results presented to examine the nature of action regulation in terms of specific strategies contextualized in the pedagogical-reasoning task. The specification of the constituent processes of this task that emanates from the present work should provide firm grounds for this endeavor.

Another conclusion was that the lower prevalence of diagnostic in authentic settings compared with the laboratory was deemed insufficient for the contingency of lesson planning on the needs of the students. The necessity of such diagnostic has to be established with appropriate content analysis of the authentic data. The condition that the academic situation of a student is not known sufficiently to plan appropriate instruction would have to be established from this analysis to concur with the hypothesized lack of diagnosis. However, the relation between expertise and an increased prevalence of diagnosis suggests that the trajectory to expertise implies an improved competence in diagnostic skills. Additional training in diagnosis should be seen as a prerequisite for the improvement of instructional planning.

The studies presented in this article show that expertise impacts how teachers represent situations, reason, plan and solve problems in pedagogical reasoning, as demonstrated previously in other performance domains by expertise research (Chi, 2006). The studies to date should be extended by the investigation of how domain knowledge supports the pedagogical-reasoning process at a finer level of analysis. In this work, pedagogical-reasoning was characterized by categories unfolding in a time order of tens of seconds, while subcomponents occur at the time order of the seconds. These categories should be related to knowledge elements that were extracted from segments of the same order (seconds). Mercier, Riopel, Potvin, and Charland (2010c) have suggested a formalism based on conceptual graph theory to map this knowledge, and provide an illustration of how this formalism can be used in the context of case studies. However, the analytic strategy to relate a problem-solving trace to a map of the knowledge, both extracted from a think-aloud protocol, remains to be determined. Again, since the verbal protocols are one of many possible indicators of cognitive processes, the technique should be complemented when possible by other traces of cognitive activity, such as neurophysiological data, eye fixations, error rates and reaction times (Ericsson, 2006). We are currently experimenting with electroencephalography and electrodermal response data to study an expert's pedagogical reasoning.

References

Anderson, J.R. (2002). Spanning seven orders of magnitude: a challenge for cognitive modeling. *Cognitive Science, 26*, 85-112. http://dx.doi.org/10.1207/s15516709cog2601_3

Anderson, J. R., Carter, C.S., Fincham, J.M., Qin, Y., Ravizza, S.M. and Rosenberg-Lee, M. (2008). Using fMRI to Test Models of Complex Cognition, Cognitive Science, 32 (8), 1323-1348. http://dx.doi.org/10.1080/03640210802451588

Anderson, J.R., Albert M.V., & Fincham, J.M. (2005). Tracing Problem Solving in Real Time: fMRI Analysis of the Subject-paced Tower of Hanoi. *Journal of Cognitive Neuroscience, 17*,(8), 1261–1274. http://dx.doi.org/10.1162/0898929055002427

Arrow, H., McGrath, J. E., and Berdahl, J. L. (2000). Small groups as complex systems: Formation, coordination, development, and adaptation. Thousand Oaks, CA: Sage.

Campbell, S.R. (2011). Educational neuroscience: motivations, methodology, and implications. Educational Philosophy and Theory, 43(1), 7-16. http://dx.doi.org/10.1111/j.1469-5812.2010.00701.x

Chi, M.T.H. (2006). Laboratory methods for assessing experts' and novices' knowledge. In K.A. Anderson, N. Charness, P.J. Feltovich & R.R. Hoffman (Eds). The Cambridge handbook of expertise and expert performance. New-York, NY: Cambridge University Press.

Chi, M. T. H., Siler, S., & Jeong, H. (2004). Can tutors diagnose student's misunderstandings? *Cognition and Instruction, 22*, 363–387. http://dx.doi.org/10.1207/s1532690xci2203_4

Ericsson, K.A. (2006). Protocol analysis and expert thought: concurrent verbalizations of thinking during experts' performance on representative tasks. In K.A. Anderson, N. Charness, P.J. Feltovich & R.R. Hoffman (Eds). The Cambridge handbook of expertise and expert performance. New-York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511816796

Ericsson, K.A. & Fox, M.C. (2011). Thinking aloud is not a form of introspection but a qualitatively different methodology: Reply to Schooler (2011). Psychological Bulletin, 137(2), 351-354. http://dx.doi.org/10.1037/a0022388

Ericsson, K.A. & Williams, A.M. (2011). Capturing naturally occurring superior performance in the laboratory: Translational research on expert performance. *Journal of experimental psychology, 13*(5), 115-123.

Gottman, J.M. et Roy, A.K. (1990). Sequential analysis : a guide for behavioral researchers. New-York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511529696

Greene, J.D. (2011). Social neuroscience and the soul's last stand. In A. Todorov, S. T. Fiske, D.A. Prentice (Eds). Social neuroscience: toward understanding the underpinnings of the social mind. New-York, NY: Oxford University Press.

Harmon-Jones, E. & Harmon-Jones, C. (2011). Social neuroscience of asymmetrical frontal cortical activity: Considering anger and approach motivation. In A. Todorov, S. T. Fiske, D.A. Prentice (Eds). Social neuroscience: toward understanding the underpinnings of the social mind. New-York, NY: Oxford University Press.

Hashweh, M.Z. (2005). Teacher pedagogical constructions: a reconfiguration of pedagogical content knowledge. *Teachers and Teaching: Theory and Practice, 11, (3),* 273-292.

Hatano, G. and Inagaki, K. (2000). Knowledge acquisition and use in higher-order cognition. In K. Pawlik and M. R. Rosenzweig (Eds). *International handbook of psychology*. pp. 167-190. London, England: Sage Publications Ltd. http://dx.doi.org/10.4135/9781848608399.n10

Johnson-Laird, P.N. (2005). Mental models and thought. In K.J. Holyoak and R.G. Morrison (Eds). The Cambridge handbook of thinking and reasoning. New York, NY: Cambridge University Press.

Kintsch, W. (1998). Comprehension : A paradigm for cognition. New-York : Cambridge University Press.

Lajoie, S.P. (2003). Transitions and trajectories for studies of expertise. *Educational Researcher, 32* (8), 21-25. http://dx.doi.org/10.3102/0013189X032008021

Legaspi, R., Sison, R., Fukui, K., & Numao, M. (2008). Cluster-based predictive modeling to improve pedagogic reasoning. *Computers in Human Behavior, 24*, 153-172. http://dx.doi.org/10.1016/j.chb.2007.01.007

Leinhardt, G. et Greeno, J. (1986).The cognitive skill of teaching. *Journal of educational psychology, 78*, 2, 75-95. http://dx.doi.org/10.1037/0022-0663.78.2.75

Lipshitz, R. & Bar-Ilan, O. (1996). How problems are solved: Reconsidering the phase theorem. *Organizational Behavior and Human Decision Processes, 65 (1),* 48-60. http://dx.doi.org/10.1006/obhd.1996.0004

McCutcheon, G. and Milner, H.R. (2002). A contemporary study of teacher planning in a high school English class. *Teachers and Teaching: Theory and Practice, 8, (1),* 81-94.

Mercier, J., Brodeur, M., Laplante, L., & Girard, C. (2010). Collaborative Learning in Teaching: a Trajectory to Expertise in Pedagogical Reasoning. In F. Columbus (Ed.) Collaborative Learning: Methodology, Types of Interactions and Techniques. Hauppauge, NY: Nova Science Publishers.

Mercier, J., Girard, C., Brodeur, M., & Laplante, L. (2010). Individual and Collaborative Learning in Teaching: a Trajectory to Expertise in Pedagogical Reasoning. Hauppauge, NY: Nova Science Publishers.

Mercier (submitted). The regulation and outcomes of performance in novice and expert individuals and dyads : the costs and benefits of collaboration. Journal of the Learning Sciences.

Mercier, J., Riopel, M., Potvin, P., & Charland. P. (2010). Vers la neuroéducation sociale: développements récents et prospectives dans l'analyse des cheminements d'apprentissage en sciences. Communication presented at the 16th international conference of the World Association for Educational Research, 31 may-4 june 2010, Monterrey, Mexico.

Newell, A. (1990). *Unified theories of cognition*. Cambridge, Mass : Harvard University Press.

Novick, L.R. and Bassok, M. (2005). Problem solving. In K.J. Holyoak and R.G. Morrison (Eds). The Cambridge handbook of thinking and reasoning. New York, NY: Cambridge University Press.

Schraagen, J.M. (2009). Designing training for professionals based on subject matter experts and cognitive task analysis. In K.A. Ericsson (Ed.). *Development of professional expertise: Toward measurement of expert performance and design of optimal learning environments.* New-York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511609817.009

Shulman, L. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, *57* (1), 1-22.

Starkey, L. (2010). Teachers' pedagogical reasoning and action in the digital age. *Teachers and Teaching, 16*(2), 233-244. http://dx.doi.org/10.1080/13540600903478433

Sun, R. (2006). Prolegomena to integrating cognitive modeling and social simulation. In R. Sun (Ed.). Cognition and multi-agent interaction. New-York, NY: Cambridge University Press.

Sweller, J. (1988). Cognitive load during problem-solving: Effects on learning. Cognitive Science, 12, 257–285. http://dx.doi.org/10.1207/s15516709cog1202_4

Tschan, F. (2002). Ideal cycles of communication (or cognitions) in triads, dyads, and individuals. Small Group Research, 33 (6), 615-643. http://dx.doi.org/10.1177/1046496402238618

Van Merrienboer, J.J.G., & Boot, E.W. (2009). Research on past and current training in professional domains: The need for a paradigm shift. In K.A. Ericsson (Ed.). *Development of professional expertise: Toward measurement of expert performance and design of* optimal learning environments. New-York, NY: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511609817.008

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of child psychology and psychiatry, 17*, 89-100. http://dx.doi.org/10.1111/j.1469-7610.1976.tb00381.x

Youngs, P. & Bird, T. (2010). Using embedded assessments to promote pedagogical reasoning among secondary teaching candidates. Teaching and teacher education, 26, 185-198. http://dx.doi.org/10.1016/j.tate.2009.03.011

Table 1. Order of the Markov chain by expertise level for lag 1

Expertise level			
	$\chi^2_{(11)}$	*p*	Number of transitions
Second year	288.81	<.001	600
Fourth year	322.22	<.001	680
Pract. teachers	166.39	<.001	325
Expert teachers	452.64	<.001	664

Table 2. Excitatory and inhibitory dependency among states in laboratory data by expertise level

States	Prep	Comp	Diag	Interv	Eval
Prep	*	2Y n.s. 4Y - PT n.s. ET -	2Y - 4Y - PT - ET -	2Y + 4Y + PT + ET +	2Y n.s. 4Y n.s. PT n.s. ET -
Comp	2Y - 4Y - PT n.s. ET -	*	2Y + 4Y + PT + ET +	2Y - 4Y - PT - ET -	2Y - 4Y - PT - ET -
Diag	2Y - 4Y - PT - ET -	2Y + 4Y n.s. PT + ET +	*	2Y - 4Y - PT - ET -	2Y - 4Y - PT - ET n.s.
Interv	2Y n.s. 4Y + PT n.s. ET +	2Y n.s. 4Y - PT n.s. ET -	2Y n.s. 4Y - PT - ET -	*	2Y n.s. 4Y + PT + ET +
Eval	2Y n.s. 4Y n.s.	2Y - 4Y -	2Y n.s. 4Y -	2Y + 4Y +	*

	PT n.s. ET +	PT n.s. ET -	PT - ET -	PT + ET +	

Note. * Structural zero

Table 3. Constituent activities of pedagogical reasoning

Category	Definition
	Problem-solving
Plan goal	Plan the goal to be achieved by this pedagogical reasoning procedure
Plan problem-solving action	Plan the pedagogical reasoning action to be carried out
Interpret state	Interpret the current problem state in pedagogical reasoning
Test conditions	Test critical conditions for applying a procedure in pedagogical reasoning
Evaluate	Evaluate the result obtained from applying the pedagogical reasoning procedure
Correct	Correct an error or provide a missing component of the solution
	Comprehension
Comprehend situation	Derive meaning of the situation
Supplement situation with prior knowledge	Provide information not included in the information available from the situation
Ask question	Diagnose a need for additional information
	Diagnosis
Elaborate a hypothesis	Make inferences to identify the problem in the case
Organize hypotheses	In the presence of multiple hypotheses, organize them in terms of plausibility
Accept hypothesis	Determine that a hypothesis is supported by the data
Reject hypothesis	Determine that a hypothesis is not supported by the data
	Planning
Identify goal	Plan the goal to be achieved by implementing the pedagogical intervention
Organize goals	In the presence of multiple goals, organize goals hierarchically
Identify pedagogical action	Identify an action contributing to the attainment of the pedagogical goal
Identify prerequisite	Identify a condition that must be met before enacting an action
Identify corequisite	Identify a condition that must be met during the enactment of an action
Identify postrequisite	Identify a condition that must be met to end an action
Identify consequence and effect	Identify the result of the enactment of an action

Table 4. Length of pedagogical-reasoning episodes by expertise level (in number of cognitive states)

Expertise	*n*	*M*	*SD*	Minimum	Maximum
Second-year (2Y)	38	125,92	140,46	2	697
Fourth-year (4Y)	50	78,44	92,71	2	391
Pract. teachers (PT)	40	94,78	86,62	7	306
Expert teachers (ET)	32	140,00	127,06	20	534
Total	160	106,11	113,25	2	697

Table 5. Prevalence of the regulation processes and of the components of pedagogical reasoning

Activities	Frequency	%
	Regulation	
Preparation	733	29
Execution	1644	64
Evaluation	190	7
Total	2567	100
	Components	
Comprehension	587	36
Diagnosis	94	5
Planning	963	59
Total	1644	100

Note. Ratios were calculated separately for regulation and components.

Table 6. Prevalence of the regulation processes and of the components of pedagogical reasoning by expertise level

	2Y (*n*=3)		4Y (*n*=3)		PT (*n*=4)		ET (*n*=4)	
Categories	freq	relf	freq	relf	freq	relf	freq	relf
			Regulation					
Preparation	192	,369	216	,317	153	,218	172	,259
Execution	268	,514	410	,601	512	,730	454	,685
Evaluation	61	,117	56	,082	36	,051	37	,056
Total	521	1,000	682	1,000	701	1,000	663	1,000
		Pedagogical-reasoning activities						
Comprehension	41	,153	156	,380	229	,447	161	,355
Diagnosis	3	,011	12	,029	27	,053	52	,115
Planning	224	,836	242	,59	256	,500	241	,531
Total	268	1,000	410	1,000	512	1,000	454	1,000

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Table 7. Test of the order of the Markov chain for the main pedagogical-reasoning components by expertise level for lag 1.

Expertise	$\chi^2_{(11)}$	*p*	Number of transitions
Second year	18.6	.068	483
Fourth year	30.8	.001	634
Pract. teachers	39.5	.001	661
Expert teachers	71.2	.001	631

Table 8. Excitatory and inhibitory dependency among states in laboratory natural setting data by expertise level

	Prep	Comp	Diag	Interv	Eval
Prep	*	4Y n.s. PT n.s. ET -	4Y n.s. PT - ET n.s.	4Y n.s. PT n.s. ET n.s.	4Y -. PT n.s. ET -
Comp	4Y - PT - ET -	*	4Y + PT n.s. ET +	4Y n.s. PT n.s. ET n.s.	4Y n.s. PT n.s. ET n.s.
Diag	4Y n.s. PT n.s. ET n.s.	4Y + PT + ET +	*	4Y - PT n.s. ET -	4Y n.s. PT n.s. ET n.s.
Interv	4Y n.s. PT + ET n.s.	4Y n.s. PT n.s. ET n.s.	4Y - PT n.s. ET -	*	4Y + PT n.s. ET +
Eval	4Y n.s. PT n.s. ET n.s.	4Y n.s. PT n.s. ET n.s.	4Y n.s. PT n.s. ET n.s.	4Y n.s. PT n.s. ET n.s.	*

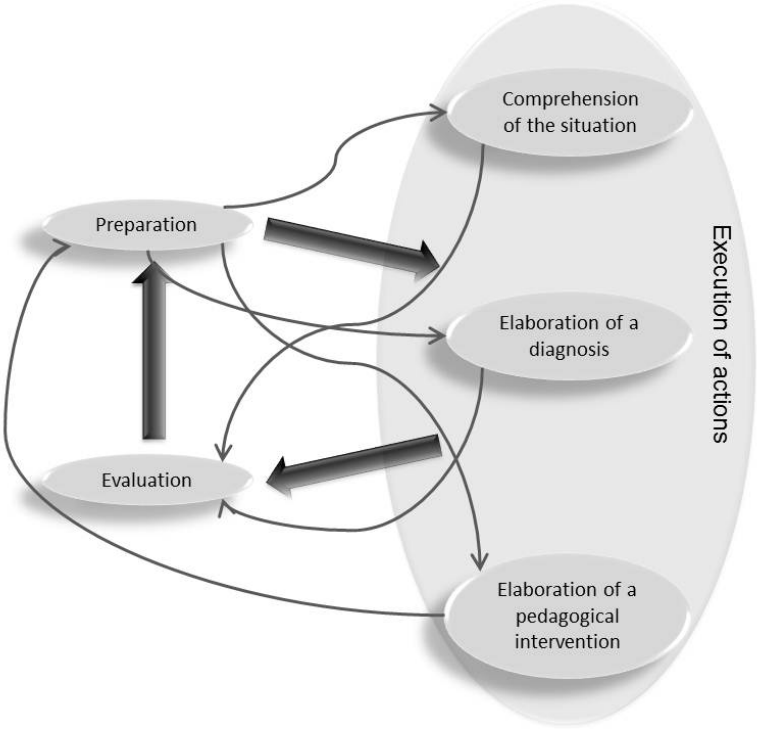

Figure 1. A model of pedagogical reasoning.

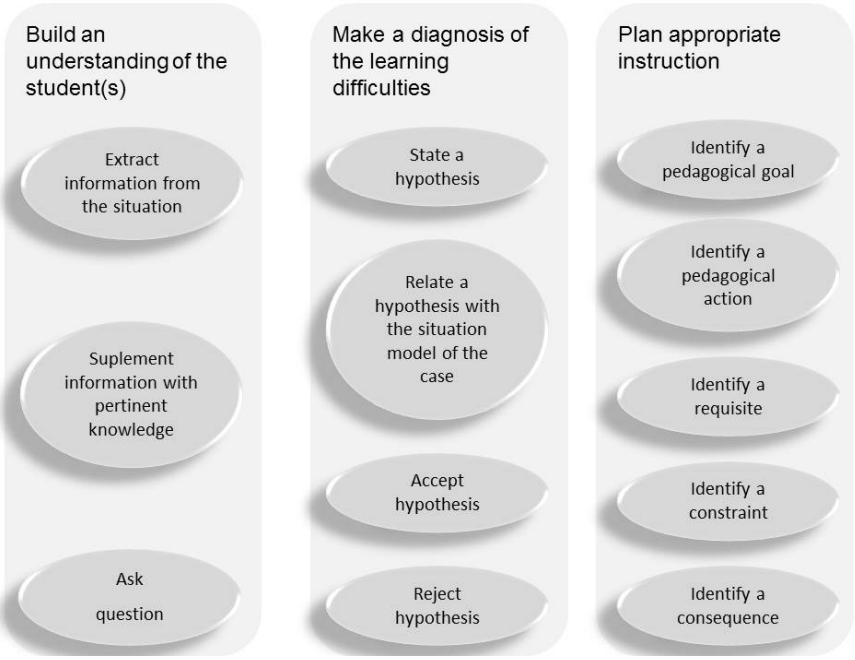

Figure 2. The constituent components of pedagogical reasoning.

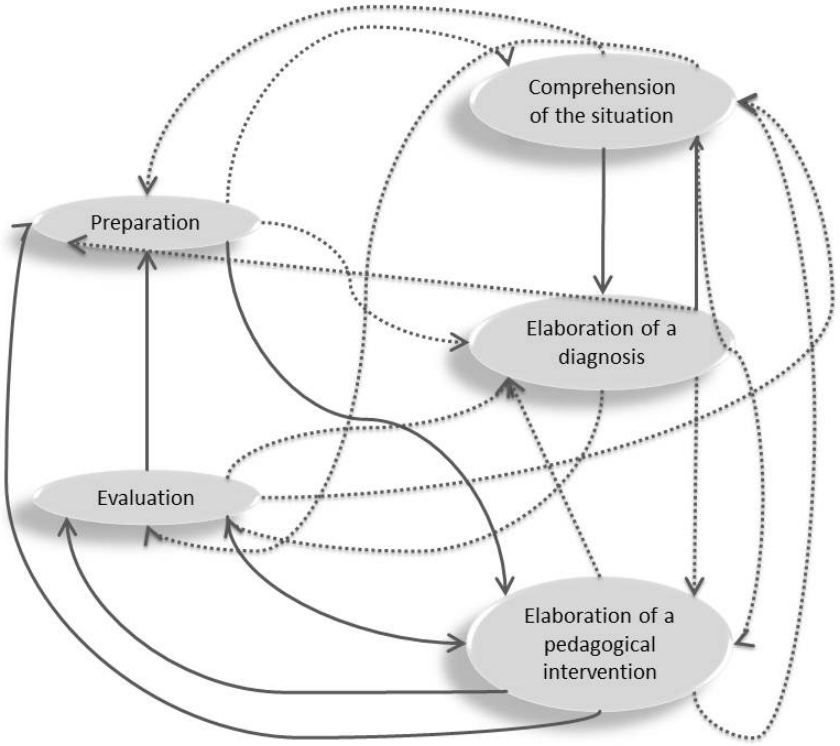

Figure 3. Excitatory and inhibitory transitions – laboratory data.

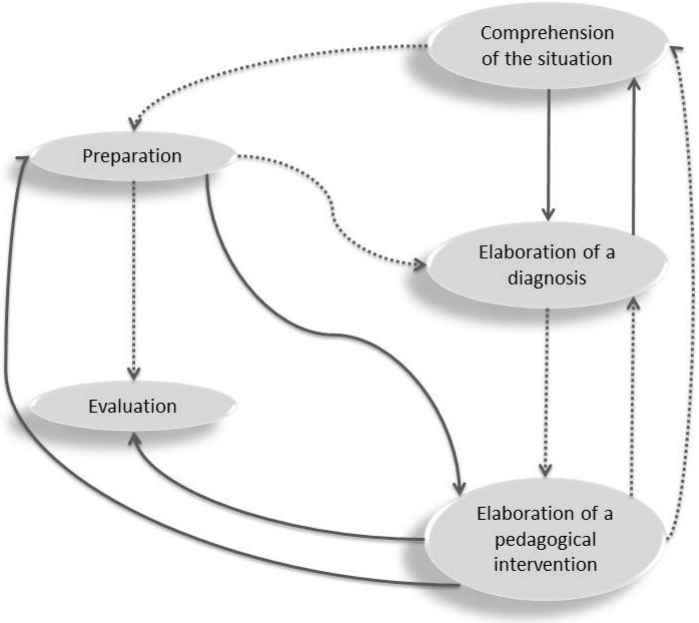

Figure 4. Excitatory and inhibitory transitions – authentic data.