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Assessment in the Use of Excel Competency for Problem Solving Using the Approach of Expert and Novice Theory

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The assessment of Competency-Based Learning (CBL) generally lacks a foundation to guide the construction of instruments that accords the nature and goals of this educational model. The measurement instruments normally used in CBL only provide a numerical score with limited information about the levels of competencies reached. This research aims to outline an assessment model that gives room to infer the individual's level of achieved competencies. The study is grounded in the theory of experts and novices and employed a mixed methodology in order not only to discover the measurement of the levels of competency from a numerical perspective but also to qualitatively understand how the students achieve a certain level of expertise in a concrete disciplinary area. The focus of this research study was on problem solving using Excel. Five professors participated in criteria selection, problem design, and the assessment process. We concluded that CBL assessment can be implemented in a more integral way when supported by theoretical frameworks that permit instructors to assess students' achievements and give more effective feedback related to their strengths and weaknesses.

L'évaluation de l'apprentissage basé sur la compétence n'a pas, de façon générale, de fondement pour guider la construction d'instruments qui cadrent avec la nature et les objectifs de ce modèle éducatif. Les instruments de mesure normalement utilisés en apprentissage basé sur la compétence fournissent uniquement une note numérique et des données limitées quant aux niveaux de compétences acquises. Cette recherche veut fournir un aperçu d'un modèle d'évaluation qui comporte une marge permettant de déduire le niveau de compétences acquises par les élèves. L'étude s'appuie sur la théorie des experts et des débutants. Elle repose sur une méthodologie mixte de sorte à découvrir comment mesurer les niveaux de compétence à partir de valeurs numériques, ainsi que comment comprendre, de façon qualitative, comment les élèves atteignent un certain niveau d'expertise dans un domaine concret. La recherche misait la résolution de problèmes en utilisant Excel. Cinq professeurs ont participé à la sélection des critères, à la conception des problèmes et au processus d'évaluation. Nous avons conclu que l'évaluation de l'apprentissage basé sur la compétence peut être mise en œuvre de manière plus intégrée quand elle est appuyée par des cadres théoriques permettant aux enseignants d'évaluer les performances des élèves et fournir de la rétroaction plus efficace sur leurs forces et leurs faiblesses.

Competency-based Learning (CBL) as we know it has been around for a little more than a century. It began along with the industrial and economic revolution in Europe. This model gained force in England and France during the 20<sup>th<sup> century by linking the educational field to the productive sector (Martens, 1997). In the United States, the model had special training relevance with the armed forces during the Second World War. Upon the arrival of cognitive theories in education, the competency model was set aside until the beginning of the new millennium when it strengthened thanks to the productive sector which demanded the training of more functional professionals.

The CBL model has been widely discussed by experts in education and curriculum (e.g., Delors, 1997; Morín, 2001; Tobón, 2006), and there is plenty of literature about the topics of complex thought, transversal competencies, training projects, and routes (Severin, 2011; Gardner, 2008 OECD, 2005). However, one point that has not been studied is performance assessment. It seems that some CBL teachers continue to assess their students with the evaluation mechanisms of traditional teaching and learning models. On the other hand, those who propose curricular developments tend to overlook the theoretical framework that sustains the assessment of students' performance according to the CBL model. Gallart and Jacinto (1995) state that the initial conceptualization of the CBL was empirical, and researchers have taken a long time to understand the need to resort to theory-based models to allow an integration and better interpretation of the information retrieved from the competencies assessment process. This is the matter that prompted the present research.

Literature Review

Performance Assessment in CBL

The process of assessment in CBL must aim to verify if the student has satisfactorily acquired a group of competencies in the areas of professional work. McDonald, Boud, Francis, and Gonczi (2000) expose three existing problems in the process of performance assessment: a) it tends to emphasize the use of mental processes such as memorization, which disregards the execution of more complex processes; b) it stimulates the students to focus only on what will be evaluated; and c) it atomizes the contents of the subjects, regarding them as isolated elements of learning without considering the interdisciplinary nature of an educational process. In view of these problems, the authors propose a methodology to evaluate performance: a) to establish the required evidences and how they will be collected; b) to make decisions based on the evidences; c) to register the results; and d) to review the procedures.

Methods like the aforementioned are present in the literature about CBL; unfortunately, they rarely sustain the process of assessment in relation to theoretical frameworks that allow us to understand which students develop competencies. One of these theoretical frameworks, which we made a base for this research, is the theory of experts and novices (Chi, Glasser, & Farr, 1988; Pozo, 1989; Reinmann & Chi, 1989; Schunk, 1997; Shuell, 1990). This theoretical framework makes it possible to understand how a novice only gradually becomes an expert. This gradual transition is what performance assessment must allow professors and students to observe during the learning process.

Theory of experts and novices. By qualifying a student as a novice, it is understood that they do not possess much experience or previous knowledge in the area or ability of reference. An expert, in contrast, has been exposed to many experiences and has acquired knowledge and abilities that support his or her expertise in the area in question (Pozo, 1989; Shuell, 1990). Research about the differences between experts and novices gained strength during the 1960's through studies in various disciplines (see Table 1).

Chi, Glasser, and Farr (1988) state that experts have the following characteristics: a) they perform better in their area of domain and they rarely become experts in other areas; b) they perceive significant patterns in their area of domain, which can be hierarchically organized; c) they rapidly resolve problems with a reduced margin of error; d) they have a higher capacity for short-term and long-term memory; e) they represent problems of their domain based on theoretical principles; f) they invest more time in analyzing a problem in a qualitative way; and g) they have more self-monitoring abilities. The theory of experts and novices can be considered as a base for performance assessment in CBL.

Competencies assessment is based on the theory of experts and novices. The process of competencies development can be seen as that in which the novice gradually becomes an expert. This takes time and advances through processes of instructions and gradual practice of the students in activities that challenge their capacities. Various authors (Champagne, Klopfer, & Gunstone, 1982; Chi, 1978; Dreyfus & Dreyfus, 1986; Fitts, 1962 & 1964) have proposed different levels of competency development. Shuell (1990) summarizes them in three main phases: a) initial, characterized by the memorization of concepts and the use of previously acquired schemes to interpret, associate, and join new information; b) intermediate, characterized by reflecting on the contents and their relationships; and c) terminal, characterized by more autonomous and automatic processes of thought and action, as well as strong knowledge structures which control behavior.

Although these phases are presented as discrete categories, development of competencies happens on a continuum. A process of assessment, as mentioned, must be oriented to locate the performance of a student on a continuum, showing how far he or she has advanced from a novice position toward becoming an expert. The foregoing ideas are applicable to understanding the development of any competency. However, this research is focused on problem solving.

Table 1

Studied Disciplines in the Theory of Experts and Novices

Disciplines in which Studies Were Conducted	*Processes Studied*	*Significant Studies*
Sports (e.g. chess, baseball))	Anticipation and decision making	Arkes & Freedman (1984); Chase & Simon (1973); de Groot (1965); Newell & Simon (1972)
Manipulation of instruments and performance in different occupations (e.g., typist)	Speed and precision in the execution of mechanical tasks	Chase (1983)
Mathematics	Problem solving and ability to reproduce patterns in diverse situations	Leinhardt (1989); Novick (1988); Thibodeau, Hardiman, Dufresne, & Mestre (1989)
Reading	Retention and comprehension of information	Jacobson (2001)
Manipulation of materials that use specific symbols and codes	Precision in the codification and interpretation of information	Gilhooly, Wood, Kinnear, & Green (1988); Postigo & Pozo (1998); Reinmann & Chi (1989); Thorndyke & Stasz (1980)

Problem solving, competency to assess. Problem solving has been characterized as a key competency for a knowledge-based society. Morín (2001), Gardner (2008), Severin (2011), and Tuning Educational Structures in Europe (2009) highlight the importance of including teaching-learning spaces in the curriculum for the development of this competency.

To Mayer (1977), solving problems is tough because it consists of searching for possible ways out of a difficulty in order to overcome an obstacle or to reach a particular goal. Schnuk (1997) defines the process of problem solving as the effort people make to attain a purpose for which they do not have automatic means. Some authors (Gick, 1986; Hardiman, Dufrense, & Mestre, 1989; Jacobson, 2001; Leinhardt, 1989; Novick, 1988; Pozo 1989; Schoenfeld & Herrmann, 1982; Sweller, Mawer, & Ward, 1983) have studied the differences between novices and experts in how they solve various problems related to multiple disciplines; chess, mathematics, and physics are among the most important. As suggested by Chi, Glaser, and Farr (1988), all of the scholars have come to similar conclusions about these differences. Thus, in order to evaluate the competency of problem solving, two aspects must be taken into consideration: a) the nature of the discipline, because it determines the type of content that will be worked with; and b) the type of problems that will be used to measure how the planned level of competency has been achieved.

It is important to highlight that solving a problem is not equal to completing an exercise. According to the OECD (2014), a problem involves:

1. Working within a real-life situation.
2. Organizing the problem.
3. Progressively departing from reality through processes such as making assumptions, generalizing, and formalizing from the presented problem.
4. Solving the problem.
5. Providing meaning to the solution in terms of the initial situation.

Another related aspect to solving problems is linked to modeling, which implies executing an abstraction process in a real situation wherein multiple variables coalesce. This kind of realistic problem solving tests competencies in ways that solving repetitive, atomized, and decontextualized problems cannot.

Considering all of this, we conducted a study in which the use of Excel was selected arbitrarily for problem solving. Excel is a technological tool created by Microsoft Corporation. Nowadays, it is estimated to be one of the most used pieces of software in the educational and productive sectors. However, its mastery is not the main purpose of this research. Rather, the study sought to make evident the different ways students use Excel's functions for problem solving purposes as they execute complex calculations in short periods of time. Thus, Excel is just a tool to which we apply the model of assessment in the novice-expert continuum.

Problem Statement

The main question of the research conducted in this study is, how can we identify the level of achievement obtained in the solution of problems in the novice-expert continuum through instruments based on the characteristics of the ability to be developed? This study is based on the assumption that it is possible to identify the student's level on the novice-expert continuum. The difficulty and main goal of this research arise in how to make the assessment.

In order to answer the research question, we must first answer three secondary questions:

1. How must the sequence of topics be structured to design adequate instruments for competency level evaluation?
2. How can exams and instruments be constructed to provide not only a score, but also the level of expertise a person possesses in the development of a competency?
3. How can a certain level of competency be inferred based on knowledge examinations?

The common denominator of these three questions undoubtedly lies in the need to know how to construct instruments that allow the measurement of competencies comprehensively, beyond a numerical score. Through answering these questions, our research seeks to establish a basis for an assessment model that improves the information quality for feedbacking the process of developing certain competencies.

Method

Considering the nature of each secondary research question, a methodology that includes both quantitative and qualitative instruments had to be used in order to obtain quality results and expand the field of knowledge in the area. The methodology that allows for the coexistence of quantitative and qualitative analysis is called Mixed Method (Johnson & Onwuegbuzie, 2004). In this study, a sequential scheme was used: First the quantitative was examined, and then the qualitative was analyzed, with a preponderance of quantitative data over qualitative.

Competency Selection

The discipline selected for this study is in the domain of the software Excel for solving problems.

Participants

Nine people participated in this study:

- Five professors who were experts in Excel who have at least three years of teaching experience. They included four women and one man aged 33 to 41. Three held official Excel Certification.
- Four novice students who reported that they had achieved basic or intermediate levels of Excel during high school or undergraduate studies. At the time of the study they used Excel for tasks related to their education. They included one woman and three men aged 20 to 22.

Instruments

The instruments created and used to measure competencies are the product of this research work. Consequently, they constitute results that are part of our proposal to outline a model of competency assessment. In order to design the instruments, three aspects were considered.

Excel problems. The Excel problems were a set of simulated problems in work situations that could be present in different scenarios. The common components of the problems was starting from a job situation in relation to data in an Excel spreadsheet, and performing a series of functions and operations with the software to solve the problem. Once the problems were designed, five experts validated them based on four criteria: Relevance of the problem at the basic evaluated level; composition, and estimated time for solution; precision of the activities' instructions; and criteria to assess the performance (see Appendix A, an example of a problem used in this study).

Experts' profile. From the listing of themes and sub-themes studied at a basic level, the degree of minimum achievement that the student must accomplish was defined in order to solve the problems satisfactorily, completing them without error and within the established time. The *expertise* scale was determined using a scale from 1 to 4; where 1 is someone without expertise, and 4 is someone with the maximum level of expertise. Five experts participated in the validation of the expert's profile associated with every problem (see Appendix B, example of an expert's profile).

Rubric to analyze the performance of a novice and expert. This instrument located students' performance through their problem solving actions. The instrument was constructed based on the main cognitive operations enunciated in the theory of experts and novices. Just as in the expert's profile, four levels of achievement were indicated; 1 is the lowest level of expertise, whereas 4 is the highest. Five experts participated in the validation of the rubric (see Appendix C, for an example of the rubric used to assess the students).

Procedure

During the study, students were asked to work on the solutions to three problems by following six steps: 1) Read the printed instructions. 2) Take only the indicated time, 30 minutes, for each problem. 3) Open the corresponding files for each problem in the Excel software. 4) Solve the problem. 5) Save the performed work. 6) Maintain a brief conversation with the researcher about how they are resolving the problem.

To assess students' performance, professors' opinions were collected around the three problems to be solved. This information permitted us to develop an expert profile to be used for comparing results and identifying both knowledge gaps, and achieved goals. A video camera was used to record the process. The recorded material was helpful as it permitted us to carefully analyze each student's process for getting to the solution.

Results

The results of this study are presented in three main sections:

1. The experience in the design and validation of the instruments.
2. The students' work while solving problems.
3. The competencies assessment process

Experience in the design and validation of the instruments

As previously mentioned, the instruments were created and used to measure competency; they are a product of the research work. The design of the instruments consisted of drafting a set of problems for which the solutions required the use of the Excel software at a basic level. Additionally, the expert's profile established the minimum degrees of achievement required for the assessed participants to indicate they had reached the desired competency for the basic level.

Finally, rubrics were designed to facilitate the assessment process and the communication of results.

Each of the three aspects of the instruments' design were validated by five experts—the professors with expertise in Excel—who were invited to participate in the study. This process was focused on the validation of the instruments' contents and the assessment process itself. Agreement by the experts helped ensure that the instruments would measure what was intended.

One of the main aspects of the competencies assessment process refers to a process of disaggregation. This is the process of separating out meso-competencies from macro-competencies and then further separating out several micro-competencies. Experts' participation was crucial in reviewing each of the competencies involved in the basic level domain of Excel. Table 2 shows the final disaggregation of the meso- and micro- competencies associated with the basic level domain of Excel.

After the disaggregation of the meso- and micro- competencies that comprise the basic level of Excel, each expert proceeded to validate the three proposed problems for the assessment process. Thus, the written expressions of the problems were revised according to the educational level of the beginner students; the identification of the involved competencies (THC and DNA in Problem 1, FHC and IHC in Problem 2, and CGR and UFO in Problem 3), the contents of the Excel databases that the student would manipulate, and the solution's estimated time until completion.

Although we expected the process of validation to achieve certain agreements, the reality is that the expert opinions were not always consistent. An example of this was seen in problem revision in which case some of the experts proposed more structured instructions to give the students hints on how to solve the problems, while others thought the problems were adequate because they were similar to what the students might encounter in their professional lives. Another example was seen in the revision of the Excel database. In this case, some of the experts suggested that it should be clean (without empty cells and with no formatting errors), while others commented that if the students could identify such issues, this would be an important aspect to verify if the they were competent. The third and last example was in the definition of the expert's profile. Not everybody agreed at which level a student could be considered to possess the competencies in question. In order to solve the controversial cases, two factors were taken into consideration: a) experts' majority opinion, and b) the congruency of such opinions with what the Excel Specialist Study Guide proposes about tasks and commands to be learned. The profile shown in Appendix B corresponds to Problem 3, which the students had to solve.

The Work of the Students While Solving the Problems

As noted in the methodology section, the students were given three problems to solve in a maximum time of 30 minutes per problem. Each student's work was recorded from two standpoints: activity on the screen and the student's manipulation of mouse and keyboard. In interviews, students agreed that the difficulty of the tasks increased with each problem. This was confirmed by the time they needed to solve each one (see Table 3).

Competency Assessment Process

An assessment of the student's performance was based on two complementary criteria. The first criterion used the rubrics shown in Appendix C. After watching the videos showing the participants' problem-solving processes, the eight variables were evaluated which characterize the behavior of an expert. Table 4 shows the scores that, according to the rubrics, the participants obtained in each one of the eight evaluated variables.

Table 2

Meso- and Micro-competencies of the Basic level of Excel

Work on a Spreadsheet (THC)	*Work with Numerical and Alphanumerical Data (DNA)*	*Format a Spreadsheet (FHC)*	*Printing a Spreadsheet (IHC)*	*Creation of Graphics (CGR)*	*Use of Formulae (UFO)*
Personalization of the toolbar (THC_1)	Enter and/or delete contents of a cell (DNA_1)	Use the functions of the bar format (FHC_1)	Use the option preview (IHC_1)	Use the assistant to create graphics (CGR_1)	Enter a range of formulae (UFO_1)
Locate toolbar to work (THC_2)	Insert and/or delete rows, columns, and spreadsheets (DNA_2)	Apply format of size, color, type, alignment, and rotation of letters and numbers to the content (FHC_2)	Print specific pages (IHC_2)	Use the preliminary view of a graphic (CGR_2)	Enter a formula by using the bar of formulas (UFO_2)
Identify the construction of spreadsheets and workbooks: book, sheet, column, row and cell (THC_3)	Use the commands to cut, paste, paste special, move (DNA_3)	Sort the data by alphabetical ascendant and descendant order (FHC_3)	Configure by using the printing options to print dividing lines (IHC_3)	Print a graphic with the option of showing the values (CGR_3)	Use the function Autosum (UFO_3)
Use the elements that allow movement in the spreadsheet (THC_4)	Tag spreadsheets (DNA_4)	Apply and remove borders and fillings (FHC_4)	Print a selection of cells (IHC_4)	Modify the position, size, and form of the graphic data (CGR_4)	Insert a formula from the option function and define its arguments (UFO_4)
Select ranges and cells (THC_5)	Copy ranges (DNA_5)		Change the orientation in a page (IHC_5)	Add and/or eliminate series of data (CGR_5)	Insert the functions of count, average, sum, minimum and maximum value (UFO_5)
Make movements on columns and rows (THC_6)	Apply borders to a cell (DNA_6)		Configure the margins and alignment of the printing (IHC_6)	Select the type of graphic (CGR_6)	Use the different types of copying formulas (UFO_6)
Use the option *Help* if needed (THC_7)			Insert and delete page breaks (IHC_7)		Create formulas with remote data (different spreadsheets) (UFO_7)
			Set printing titles (IHC_8)		
			Establish headlines and footnotes (IHC_9)		

Table 3

Time (in minutes) Invested by the Students to Solve the Three Presented Problems

Problems	*Student 1*	*Student 2*	*Student 3*	*Student 4*
Problem 1	14	13	14	30
Problem 2	11	23	20	25*
Problem 3	25	16*	22	18*
Average by problem	16.67	17.33	18.67	24.33

Note: In these cases, the student used the indicated time for the process of solving problems without producing the expected result.

Table 4

Scores Obtained by the Four Students on Eight Variables, Three of Which Solved Problems (P1, P2, P3)

	Student 1			Student 2			Student 3			Student 4		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
Memory	4	4	3	3	3	2	4	3	3	3	3	2
Comprehension time	4	4	3	3	3	2	3	3	3	3	3	3
Automatization	4	4	3	2	2	1	4	4	3	4	3	2
Analogical Thinking	4	3	4	4	3	1	3	3	3	3	2	1
Information categorization	4	3	4	2	2	2	4	3	3	3	2	2
Hierarchy	4	3	4	2	2	2	4	3	4	3	2	2
Verbalization	3	4	4	2	3	2	3	3	3	3	3	2
Monitoring	3	4	4	2	3	2	3	3	3	3	3	2
Subtotal	30	29	29	20	21	14	28	25	25	25	21	16
Total		88			55			78			62	

The subtotals must be interpreted in relation to the total score of 32 points, while the totals are in relation to 96 possible points. Every assigned scored problem confirms what the participants reported during the interviews; they reported that the third problem was more complex that the second, and that the second was more complex than the first. Although Student 1 obtained the best score in a shorter amount of time than the other three participants, it is important to mention that there is no necessarily correlation between scores and time in the other participants.

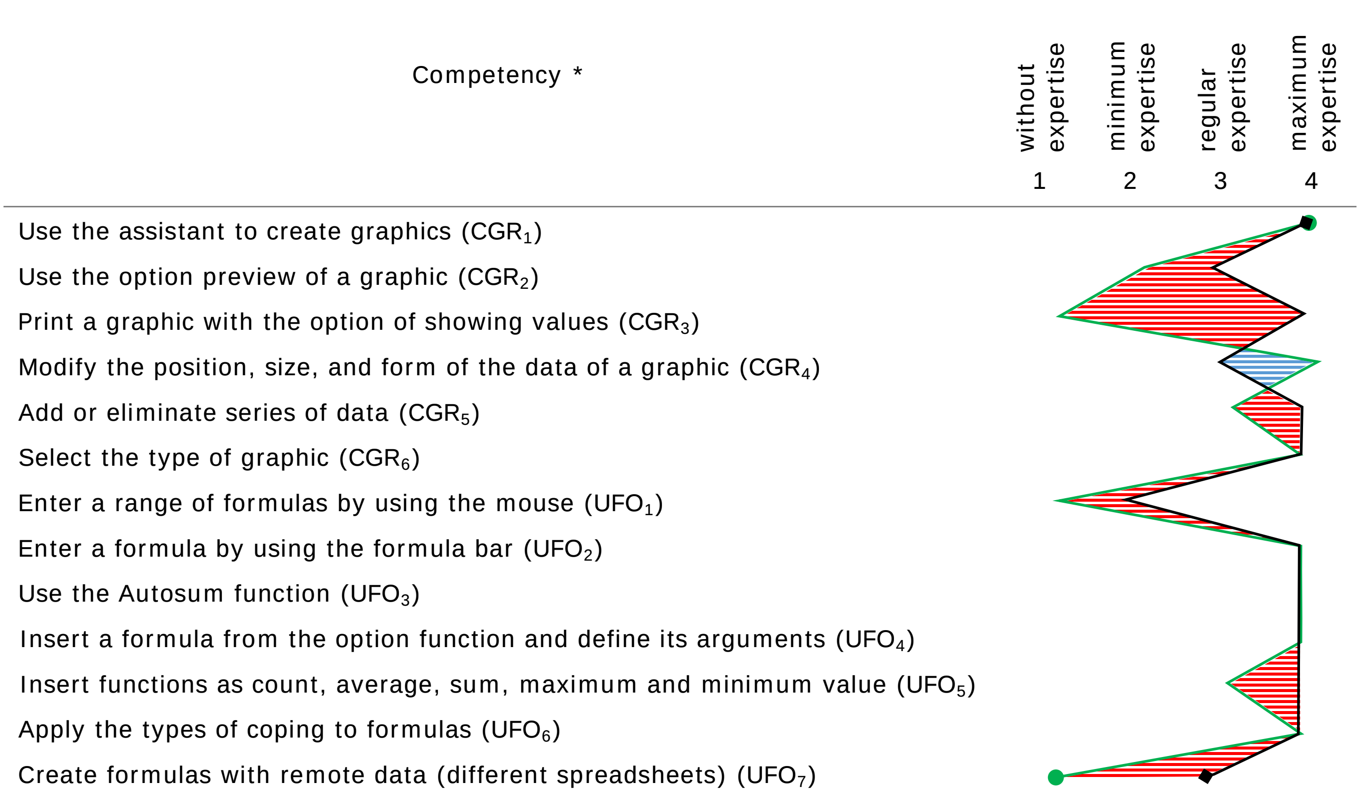
The second assessment criterion reflected a comparison between each participant's performance profiles against the expert's profile, which was defined *a priori* in each problem. The profile comparison was important to infer each participant's level of competency. Figure 1 is a representation of the assessment result.

The combination of the scores that derive from the rubric and expert's profile offers the students precise information about their areas of opportunity to continue developing the desired competencies. Following is an example of the type of feedback that can be given to the participants:

In Problem 3, on a scale from 1 to 4, with 1 being without expertise and 4 being maximum expertise, Student 2 is located at an average level of 2. The student urgently needs to study and practice the use of basic formulas to perform simple operations such as addition, subtraction, filtering the minimum and maximum values of a database, and working with values from one spreadsheet to another within the same workbook. These kinds of operations with formulas should be applied in less than 10 seconds each. Study and practice on these items will also help develop the student's analogical thinking in the hierarchy of actions, which will lead to better decision making the next time the student does the task.

Discussion

The presented results offer answers to the three secondary research questions. The first question asked, how must the consecutiveness of topics be structured in the development of a competency to construct adequate instruments for its assessment? Based on the theoretical framework of this study (Chi, Glaser, & Farr, 1988; Pozo, 1989; Reinmann & Chi, 1989; Schunk, 1997; Shuell, 1990), it was possible to identify how the thinking processes evolve and improve in accordance with the strengthening of the domain of the discipline. Being aware of this evolution lets the professor design processes and instruments to improve student assessment and



Note: The red areas indicate that the participant is underqualified, therefore could not be declared an expert in certain topics, while the blue areas indicate that the participant is overqualified.

Figure 1. Contrast between the participant's performance profile (Green) and the expert's profile (black) of student 3 working on the Problem 3

feedback regarding their academic performance, their strengths, and their areas for improvement to achieve optimum levels in the development of their abilities.

The second secondary question inquired, how can exams and instruments be constructed to provide not only a score, but to indicate the level of *expertise* a person possesses in the development of a given competency? The answer to this question is centered in the process that enabled the design of the instruments. For research purposes, it was necessary to accomplish four processes to estimate the performance: (1) determine the elements of the competency and in consequence, to define the sublevel in the establishment of the problems; (2) to define the expert's profile; (3) to establish the problems to be solved and; (4) to determine the criteria that allowed the design of the rubrics for the performance assessment. These processes resulted in the creation of the problems to be solved, and the rubrics for its assessment.

The process of validation was an additional enriching point. Having the judges' expert opinions was valuable because they were involved in other types of construction of instruments which could be more aligned to their work as educators in the area of competency development. Furthermore, their participation in the study allowed them to develop a set of definitions about evaluation, which would be the ideal practice in benefit of a better means of measurement of competencies. This corresponds to the work of Pasturino (1999) who argues that one of the greatest challenges of CBL instruction is learning to work in networks to promote better decision making in relation to didactic strategies and evaluation.

The third secondary question examined, how can a certain level of competency be inferred based on knowledge examinations? The knowledge test in this case broke from traditional schemes of questions that seek precise and specific answers. However, the application of the problem and the registry in video and analysis enabled the assessment of each student's performance and, in consequence, the identification of his or her competencies. The traditional assessment instruments (close-end multiple choice questions, short answers, and matching columns) would not have produced precise information about the students' constructed and applied knowledge.

It is important to mention that after the application of the problems, based on the theory of experts and novices (Gick, 1986; Hardiman, Dufrense, & Mestre, 1989; Jacobson, 2001; Leinhardt, 1989; Novick, 1988; Pozo, 1989; Schoenfeld & Herrmann, 1982; Sweller, Mawer, & Ward, 1983) we verified that the expert students worked faster on a given problem and invested less time to comprehend the situation and to proceed and formalize their actions. After completing the problems, they provided solutions focused on the initial questions. In contrast, the less expert students were prone to using their knowledge without a precise visualization of the problem and without complete comprehension; they tried to solve small problems as they identified them without holistically considering the situation. This is consistent with the reports by the OECD (2014) about the process of problem solving in real contexts.

Conclusion

The main research question examined how can we identify the level of achievement students obtain as they solve problems in the novice-expert continuum by inferring levels through constructed instruments based on characteristics of the ability to develop? Certainly, working in the CBL framework demands the integration of several elements such as the determination of macro-, meso- and micro- competency, a theoretical basis to comprehend the scope and limitations, the definition of goals for each level, and the selection of techniques applied to the assessment and definition of adequate instruments to achieve the observation and subsequent opinions about the performance. All these factors provide the foundation of our proposed assessment model.

In light of the above, and as an answer to the main research question, it is pertinent to present altogether the elements needed to construct an assessment model. In this holistic way, it is possible to observe what has and has not been accomplished in the frame of CBL framework. The proposed assessment model to estimate the achievement of competencies is comprised of five elements:

1. Definition of a graduate profile and, in consequence, the determination of macro- and micro- competencies.
2. Distribution of the themes and sub-themes based on their application to different problems.
3. Determination of the quantity of phases in the teaching process, according to the nature of the subject.
4. Collegial participation of experts in the disciplines regarding the determination of topics that needed to be studied.
5. Determination of the type of instruments which allows inferring the results and providing feedback to the students about their accomplishments of competencies.

An assessment model for CBL, as seen in this research, represents the combination of educational principles that schools must uphold in committing to develop the expertise to help both teachers and students detect and understand the processes for achieving an expert-level profile.

For the aforementioned reasons, we conclude the following four points. a) It is necessary to establish the differences between the assessment process in the development of competencies inside the school and the process of verification or certification of competencies. (Further, these differences must be reflected in an adequate model for the CBL assessment). b) It is indispensable that teachers involved in CBL are trained in assessment strategies that can be established in the continuum of the teaching process and competencies development. c) It is necessary to find the CBL elements in learning theories to sustain the educational practices. d)

The constant practice of planning and decision-making about assessment must be considered, which derives from the reformulation of curricular design and teachers' didactic disciplines according to the results of the learning assessment. Undoubtedly, this demands training and updating in the topic of learning assessment.

For future studies, we recommend the design of instruments assisted by simulators (computer-based tests), which should be constructed under a theoretical basis that facilitates the examination task. Although disciplinary fields vary, this research could have wide applications in proposing systems for CBL concerning learning through Excel, which constitutes an important tool in the work field.

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Appendix A: Example of a problem to be solved by the students

The Inteltec enterprise administered an exam last weekend to the applicants of the Production Coordinator position. The selection process was difficult, but finally the candidates were selected. They will go through a personal interview as a last evaluation before knowing who will have the job. The human resources manager asked a member of the department to present the exam results in a graph in order to send the data to the plant manager. The member of the human resources team is facing a problem: the person who collected the results didn't format the spreadsheet, mixing the results of men and women, and did not organize the list of men and women in descending order according their scores on the exam.

Some of the particulars are:

1. Concerning the way the information must be organized in the sheet 1 and 2: The corresponding results of men candidates must be on sheet 1 and the women on sheet 2 along with their name. The results must be in descending order and the required values must be written in column D.

Required values:

- Average score of the group of men and women
- Number of candidates for both cases who surpassed the score of 8
- Maximum value obtained in the exam

2. Concerning the graphics: The graphics must be designed according to the results and they must be on sheet 3 with the corresponding title and caption on the left side. The workbook sheet must be named, as well.

The specifications are:

- Generate a table in a new sheet with the average for men and women. Based on the table, proceed to design:
- Graph 1 must be a bar graph, on which the average results can be compared between men and women. Attention: only two comparative columns can be included.
- Graph 2 must be a pie graph, which shows a colored "slice" with the percentage of candidates from both sexes who achieve a score higher than 8, against the other scores.

Appendix B: Example of an expert's profile

Competency	without expertise 1	minimum expertise 2	regular expertise 3	maximum expertise 4
Use the assistant to create graphics (CGR_1)				♦
Use the option preview of a graphic (CGR_2)			♦	
Print a graphic with the option of showing values (CGR_3)				♦
Modify the position, size, and form of the data of a graphic (CGR_4)			♦	
Add or eliminate series of data (CGR_5)				♦
Select the type of graphic (CGR_6)				♦
Enter a range of formulas by using the mouse (UFO_1)		♦		
Enter a formula by using the formula bar (UFO_2)				♦
Use the Autosum function (UFO_3)				♦
Insert a formula from the option function and define its arguments (UFO_4)				♦
Insert functions such as count, average, sum, maximum, and minimum value (UFO_5)				♦
Apply the types of copying to the formulas (UFO_6)				♦
Create formulas with remote data (different spreadsheets) (UFO_7)			♦	

Note: CGR: Create graphics; UFO: Use of formulas

Appendix C: Example of the rubric to assess students

Variable	*Score 1*	*Score 2*	*Score 3*	*Score 4*
Memory	Did not know how to execute commands or their location in the taskbar.	Remembered some execution commands but did not know their location in the taskbar menu or vice versa.	Remembered some of the execution commands and their location in the taskbar menu.	Remembered most and/or all of the execution commands and their location in the taskbar menu.
Time of comprehension	Took 10 to 15 minutes to start the exercise, follow the instructions, and solve the problems.	Took 5 to 10 minutes to start the exercise, follow the instructions, and solve the problem.	Took less than 5 minutes to start the exercise, follow the instructions, and solve the problem.	
Automatization	Took 30 to 60 seconds to execute each one of the necessary functions and fulfill the requirements of each step of the problem.	Took 10 to 20 seconds to execute each one of the necessary functions and fulfill the requirements of each step of the problem.	Took 5 to 10 seconds to execute each one of the necessary functions and fulfill the requirements of each step of the problem.	Took less than 5 seconds to execute each one of the necessary functions and fulfill the requirements of each step of the problem.
Analogical thinking	The student did not identify any similar previous situations that helped clarify the required steps to solve the problem.	The student identified one similar previous situation that helped clarify the required steps to solve the problem.	The student identified several previous situations that helped clarify the required steps to solve the problem.	The student identified multiple similar previous situation that helped clarify the required steps to solve the problem.
Categorization	The student could not identify the topics that compose the parts of the problem.	The student identified certain topics that compose the parts of the problem.	The student identified almost all of the topics that compose the parts of the problem.	The student identified all of the topics that compose the parts of the problem.
Hierarchy	The student did not identify the order of the steps that had to be followed to solve the problem.	The student identified the order of some of the steps that had to be followed to solve the problem.	The student identified the order of almost all the steps that had to be followed to solve the problem.	The student identified the order of all the steps that had to be followed to solve the problem.
Verbalization	The student could not narrate what he or she did to solve the problem.	The student could briefly narrate what he or she did to solve the problem.	The student could accurately narrate what he or she did to solve the problem.	The student could accurately narrate what he or she did and added ideas to the narration about alternative ways to solve the problem.
Monitoring	The student is able to evaluate the work in a comprehensive manner but did not identify specific points that could be improved.	The student was able to evaluate some aspects that led to the solution of the problem.	The student was able to evaluate several aspects that led to the solution of the problem.	The student was able to evaluate all the aspects that led to the solution of the problem and added ideas to improve the instructions or the problem.