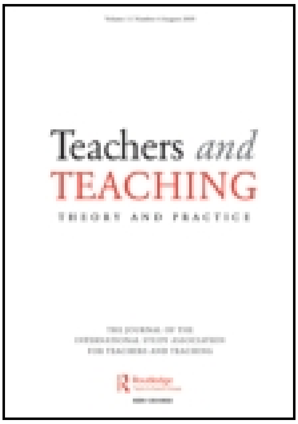

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Heuristics diagrams as a tool to formatively assess teachers' research

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Many teacher education programs include different forms of teachers doing research. Be it in the form of action research or general inquiries about their practice, it has been argued that when teachers do research on their own practice, they are able to take a more reflective stance towards their work which is necessary to bring about educational change. However, it is hard to find tools that can be used to provide clear feedback in developing such research. In this paper, we present the results of using a heuristic tool called 'heuristic diagram' (HD), previously designed by the authors and based on Gowin's heuristic Vee, to formatively assess in-service teachers' research skills. Two different groups of science and mathematics in-service teachers in a Research Methods Course completed four different HD about their research project throughout the semester. We performed a general analysis based on a scoring rubric of these HD in order to show how teachers' research skills were developed throughout the course. Teachers also evaluated their experience of using the HD through a semantic differential analysis and answered an open questionnaire about the advantages and difficulties of using such tool. Overall, the HD seems to be useful to formatively assess research skills because it allows teachers to make their theoretical framework explicit, relate it to the research question and to the methods used to answer it in an integrated and short way.

Keywords: In-service teacher education; teacher researchers; research skills

Rationale and introduction

Teacher research or practitioner research has been regarded as a fruitful way to develop teachers' knowledge and improve teachers' practice (Altrichter, Feldman, Posch, & Somekh, 2008; Cochran-Smith & Lytle 2009; Loughran, Mulhall, & Berry, 2004). Terms like 'research-based teacher education' have been used to describe a general approach that emphasizes the development of teachers' knowledge, skills, and disposition to become reflective practitioners (Reis-Jorge, 2007).

It is expected that teachers undertaking research on their own practice take a more reflective critical stance which could eventually improve their teaching practice. By being involved in the generation of knowledge about issues relevant to their academic lives, teachers become empowered and assume responsibility for their own knowledge (Justi, Chamizo, García-Franco, & Figuereido, 2010). Teacher research has also been found to improve pedagogical content knowledge, especially

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for science teachers (Garritz & Trinidad, 2004; Loughran et al., 2004; Shulman, 1986).

However, even if it is assumed that teachers doing research could improve educational practice, it has not been widely documented how teachers learn the skills necessary to undertake research (e.g. ask good questions, recognize a methodology capable of achieving a response, use adequate frames of reference, etc.) and there is a lack of description of practical tools that can be used to assess how these skills are developed (Cochran-Smith, Barnatt, Friedman, & Pine, 2009). We have recently worked on the development of instruments to improve learning in different fields (Chamizo & Izquierdo, 2007). In this paper, we aim to show that one of them – the heuristic diagram (HD) – is a very practical tool that helps teachers establish relations between concepts (theoretical frameworks), methodologies, and results of a research project, as well as to formatively assess teachers' research skills. The use of the HD provides teachers with feedback (Schute, 2008) on their research projects and stimulates teacher professional learning through doing research but it also aims at developing teachers' ability to become lifelong learners able to pose and address problems and challenges that do not have existing answers Darling-Hammond, & Bransford, 2005).

Theoretical framework

Heuristic diagram

The Vee heuristic is a graphic organizer developed years ago by Gowin (Novak & Gowin, 1984) with the purpose of helping students understand their research processes. This instrument has been used for understanding knowledge production in different fields (Calais, 2009; Fox, 2007; Gowin & Alvarez, 2005; Keles & Özsoy, 2009; Sillitoe & Webb, 2007) and also for diagnostic, formative, and summative assessment (Doran, Chan, Tamir, & Lenhardt, 2002).

Graphic organizers have been valued for representing thinking processes, they can be considered *a cartography of cognition* (Wandersee, 1990) and even though Gowin recognized the initial difficulty of students in producing Vees, particularly the time required becoming competent, he also recognized its value: *Students recognize that Vee making, besides being less tedious than writing reports, helps them to gain understanding of the subject matter* (p. 113).

The heuristic Vee consists of five parts: facts or events that trigger research in the bottom, a research question in the center, a methodological–practical right side that shows what must be done to answer the question, a theoretical–conceptual left side, that shows the frame of reference for interpreting the question, and finally the response, not necessarily incorporated into the Vee. One of the main qualities of the Vee is that it explicitly relates the conceptual–theoretical aspects of a research question with the practical aspects through a research question.

However, the left side of the Vee, the theoretical–conceptual side, is regarded as difficult because the relationship between philosophy, theories, principles and laws, and concepts (Giere, 1999) is not always clear for the users. In brief, despite its virtues, one of the greatest difficulties of using Gowin's Vee is its' left side ambiguity. For example, sometimes a concept map can be included (Doran et al., 2002), sometimes not, sometimes a model or a theory, or neither. Improved versions of the Vee diagram which clarify the constructs proposed by Gowin have been constructed and used by Åhlberg and Ahoranta (2002) with geography students. However, further improvements are needed in order to better recognize the relevance of the theoretical constructs because Gowin does not recognize, for example, the difference between names and concepts (2005, p. 56): *We define concept as a name*.

An improved version of the Vee diagram: the HD

To aid with the clarification of the Vee's left side, we introduced several modifications following the Toulmin's (1972) philosophical approach. The work of English philosopher Toulmin (2003), *The uses of Argument*, has provided a valuable foundation for science education and there are now many examples of research based on his proposals (Chamizo, 2007; Erduran & Jiménez-Aleixandre, 2008; Osborne, Erduran, & Simon, 2004). Toulmin's work provides an overview of science that entails the dynamic view of scientific knowledge, with attention to the social context. This could be extremely useful if we consider that science (and learning how to teach science) is also a dynamic process in which new knowledge emerges. Toulmin (1972, p. 35) defines a concept through its historical–social interaction, which is useful for the purposes of characterizing an evolving research such as the one undertaken by teachers: *Each of us thinks his own thoughts; our concepts we share with our fellow-men*. Science (and science teaching) is not a static enterprise; rather its concepts, interest, presuppositions, and theories are dynamically evolving (1972, p. 161):

> In order to do proper justice to the 'complexity' of scientific concepts, we must distinguish three aspects, in the use of those concepts: namely (i) the language, (ii) the representation techniques, and (iii) the application procedures of science. The first two aspects or elements cover the 'symbolic' aspects of scientific explanation – i.e. the scientific activity that we call 'explaining' – while the third covers the recognition of situations to which those symbolic activities are appropriate.

Recognizing that each scientific concept requires three different aspects for its complete understanding – applications, language, and representation techniques – can clarify its development overtime. In the HD, the left side considers Toulmin's concepts (language, models as representation techniques, and application procedures).

Furthermore, the HD considers two dimensions for concepts: scientific and pedagogical. So, for example, if teachers were to develop a didactic intervention to teach 'chemical bonding' they should recognize what is chemical bonding, how is it represented, and why it is important but they should also acknowledge what is the theoretical framework that supports their teaching approach, how it is represented, and what is its application realm. By including the pedagogical and scientific framework, teachers can develop their pedagogical content knowledge which is seen as highly relevant to improve practice (Garritz & Trinidad, 2004; Loughran et al., 2004).

Just as Vee diagrams, HDs can be used as a tool to develop research (Chamizo, 2012) because it helps identifying all the elements of the investigation (Trowbridge & Wandersee, 1998).

In the Appendix, we present a HD with instructions for completion: the left side for concepts in two dimensions, the center column for methodology, and the right column for students' self-assessment.

Using HD for formative assessment

We are proposing the use of the HD as a tool to formatively assess teachers while they are developing their research project. Formative assessment has been shown to open up and promote desirable changes in the classroom through three key processes (Black & William, 2009; Porter, Youngs, & Odden, 2001): establishing where the learners are, where they are going, and what is needed to get them there. Formative assessment provides evidence about students' achievement which is interpreted to make decisions about what to do next (Sadler, 1989). The idea is that judgments about the quality of student responses are used to shape and improve students' competency by clearly stating what is expected and where are the inconsistencies and aspects that require specific attention.

Heuristic tools such as the HD, when used in a supportive environment which incorporate feedback loops, can bring about actual change in teachers' skills and conceptions (Black & William, 2009) because they help in establishing a framework from where to start organizing or developing the research project (Feldman, 1994) especially when teachers are not familiar with educational research.

Another crucial aspect in formative assessment is providing the means by which peers become learning resources for each other (Black & William, 2009).The fact that HDs are made public (available for all teachers) helps activating students as instructional resources for one another, and the rubric for self-assessment makes teachers aware of their role as owners of their learning. It is very important to get the class to work as a community of practice where there is mutual engagement, a joint enterprise, a shared repertoire (Capobianco & Feldman, 2006), and where teachers serve as critical friends of each other. The use of a rubric as a way to self-assess performance has been reported to clarify the assignment, help teachers reach their learning objectives, and also provide an effective, efficient, equitable self-assessment method (Schneider, 2006). Ross and Bruce (2007) have also recognized self-assessment as a very important mean of bringing about teacher change and facilitating professional growth.

Research questions

Two main questions guided the development of this project:

- Can teachers' research skills be assessed in a reliable and simple way using HDs?
- How do teachers value the HD as a tool to develop their own research?

Research methods

Context

We used the HD as a formative assessment tool in a Research Methods Course in a Master degree in the National Autonomous University of Mexico (UNAM). This master degree is designed for in-service high school teachers trained as scientists or engineers without experience in educational research and with different years of experience as high school teachers. Currently, graduation rates in this program are rather low, and a large proportion of the participating teachers usually take at least double of the time allowed. Graduation requirement for this master degree is the completion of a dissertation that is presented written and defended in an oral examination.

The Research Methods course we teach is delivered in the third of four semesters and is intended to be a space where teachers learn the basics of educational research and develop their research project. However, when teachers get to this course, it is likely that they have different degrees of advancement in their project. During the 16 weeks of the course (that meets once a week for three hours), teachers pursue a process of continuous iteration in developing their own research project. In total, four different HD are completed, shared in the classroom – where they are intensively discussed– and self-assessed. The rubric for self-assessment was constructed through a discussion with the teachers with the aim not only of evaluating the HD but also to serve as a guide for learning how to construct the HD (see Appendix). The teacher educators comments and discusses all the diagrams, but only the last one is actually marked using the same rubric and incorporating teachers' self-assessment to the mark.

Participants

The HD was used with two different groups (G1 and G2) of teachers. The first group (G1) is comprised by six chemistry teachers from three different high schools. The second group (G2) is comprised of three physics teachers, one chemistry teacher, and one mathematics teacher. Different teacher educators (the authors of this paper) taught the courses in consecutive years.

Data collection

We have three different sets of data for analysis:

- The HDs produced by the teachers during the courses along with the rubrics they used for self-assessment.
- A semantic differential (SD) completed by teachers to evaluate their attitudes towards the HD.
- An open questionnaire with questions about the usefulness and difficulties of the HD and its impact on their research project was answered by teachers of the second cohort. The questionnaire was sent by email three weeks after completing the fourth diagram and once course grades had been released.

Data analysis

Development of research skills

The HDs were collected and analyzed using the same rubric that teachers used for self-assessment (see Appendix). This rubric recognizes fundamental research skills such as acknowledging the facts that trigger the research question, asking a good research question, devising a feasible methodology, recognizing relevant concepts (in their three dimensions: language, applications, and models), and providing answers to the research question. Validity and reliability of this rubric was established mainly by discussing it with the teachers and by comparing teachers' self-assessments to teachers' assessment. After teachers had completed the course and for research purposes, the HD were rescored by both authors to ensure reliability and also to make a more qualitative analysis of the kind of improvements that were evident from teachers' HD. Due to space limitations, we only present some examples of the research skills which development can be appreciated in the diagrams with the purpose of providing detailed examples of the possibilities provided by the HD.

Teachers' attitudes towards the HD

To evaluate teachers' attitudes towards the HD, a semantic six-point differential scale with 12 items was used (Chamizo, 2012; Robson, 2002). In this test, a person states his agreement with one or the other of a pair of contrasting adjectives. Items belonging to three dimensions previously identified – Evaluation (overall positive meaning), Potency (overall importance), and Activity (the extent to which the subject is associated with action) – were selected (Heise, 1970).

Open questionnaire

An open questionnaire was only answered by the second group of teachers because we realized that we needed more elements to evaluate teachers' perceptions about the use of the HD. Teachers' answers to the questionnaires were openly coded by the second author and shared with the first author for intercoder reliability.

Results and analysis

Self-assessed scores and instructor scores for every aspect of HD were compared allowing for recognition that research skills considered in the rubric actually improve throughout the semester.

We present the case of one teacher whose scores improved in the course of the semester regarding two of the most important research skills developed by teachers: asking productive questions and providing with complete answers. We aim to show how using the HD actually develops teachers' skills by making evident certain aspects of her research.

Asking productive questions

One skill that is considered relevant for teachers is their ability to frame productive questions. The reiterative use of HD helps teacher in developing such skill. Table 1 shows the change in the questions from one teacher concerned with developing a teaching–learning sequence about acids and bases. Besides parameters explicit in the self-assessment rubric, we analyze the questions in terms that they are structured with precision and clarity are univocal (i.e. their meaning is the same for different subjects) and feasible (i.e. that can be answered in the particular research conditions).

As can be seen, from the second to the fourth HD, the complexity of the question grows. In the first HD, the question is immediate, not thoroughly thought, and even innocent (in not recognizing any complexity related to learning). The question

Table 1. Examples of the evolution of research questions.

HD	Question	Points
Second	How will the learning process of students studying acids and bases will be affected if a proposal focused on Brønsted–Lowry' model is used?	1
Third	What effect will studying acids and bases from a didactic approach based on Brønsted–Lowry' model have in the process of learning, through promoting a better understanding of the implications of the model that contributes to reduce the generation of alternative concepts and allow the restructuring of misconceptions in order to understand the chemistry of acids and bases?	2
Fourth	What effect will studying acids and bases from a didactic approach based on Brønsted–Lowry' model will have on the learning process, promoting a better understanding of acid–base concepts and allowing students' progress in the process of redescription of their representations concerning acids and bases to access concepts of greater cognitive demand?	3

in the second HD is also specific, but much more complex because it incorporates facts such as the recognition of alternative conceptions (it means, concepts from pedagogy are included). Finally, in the last HD, the teacher assumes that, in addition to recognizing alternative conceptions, the advantages and limitations of Brønsted-Lowry' model should also be considered, i.e. there is something like 'how' to learn more and better. That is, she went from proposing a more general (and therefore less feasible) question (how will a learning strategy affect the learning process) to a more feasible one (what effect will a learning strategy have on the learning process). The terms used by this teacher (representational redescription) point out to specific theoretical underpinnings (Karmil off-Smith's work in this case). Incorporating theoretical aspects in the question (as demanded by the rubric) could also help make connections with the methodology and analysis of the results.

Producing more detailed answers

Regarding the answer to the research question which should integrate the concepts (in both dimensions) and the methodology, the teacher working on the chemistry of acids and bases had no response in the second HD. However, the answer in the fourth was:

> Given the difficulties faced by students to approach the study of acids and bases that are largely due to the way that traditionally addresses the topic in the classroom (de Vos 200; Furio et al., 2005; Dreschler, 2005) we designed a didactic sequence from a historical-conceptual framework (Caamaño, 2006) with a progressive increase in the degree of difficulty that would study the acids and bases from the Brønsted-Lowry' model. Our preliminary results indicate some progress in the learning process as students were able to associate some of the information they had with the new information; tested some alternative conceptions from the Arrhenius model and were able to confirm the explanatory potential of Brønsted-Lowry' model, when compared to the Arrhenius model.

In this particular case, the teacher went from having no answer (in the second HD) to articulating a very clear one to her research question about the effects caused in students' learning by the use of a particular teaching approach. As can be extracted from her answer, there is a recognition of the theoretical framework, a brief description of the teaching approach, and a relation with the methodology and some results (such as students' exhibiting the ability to relate information). Of course, such enormous change could not be only attributed to the formative assessment provided by the use of the HD, but also teachers' effort was enormous and she was able to undertake field work and have some partial results, etc. However, having a heuristic tool where teachers are able to express what they are learning and developing as part of their research project and that can be compared to their peers (since everyone is completing a similar HD) seems to be very valuable as can be inferred from teachers' attitudes towards the diagram which we analyze next.

Conceptual framework and general quality of the research project

The final HD of one student can be seen in Figure 1. This diagram was one of the best ones developed during the course and is used to illustrate specific aspects related to the conceptual framework. It is clear from this HD (Figure 1) that the teacher had to perform a preliminary investigation to identify the facts which give theoretical support to his question. This is not always common in teachers' research projects but is regarded as relevant for teachers' development (Cochran-Smith et al., 2009). As can be seen, distinguishing the three aspects of concepts in their scientific and pedagogical dimensions allows teachers to make the theoretical framework explicit in both dimensions.

From this diagram, it is possible to show that there is a clear relationship between the question and the answer obtained through the methodology indicated. The use of the self-assessment rubric (Appendix) allowed for explicit recognition of different aspects relevant to the research process, it aims to clarify each part of the HD and its relations to the other parts. This allows, in a simple way, for explicit recognition of progress against an established standard. The teacher-author of this HD assessed with 16, 18, and 19 points of his successive HD, which can also be regarded as an evidence of his own recognition of change which would be expected from formative assessment tools allowing for productive feedback.

Teachers' perceptions of the HD as a tool for developing research using a SD analysis

We recognize that caution needs to be taken when interpreting SD data for a small sample size. However, as indicated in Table 2, teachers were positive about the value of HD, with a mean of 4.7 (scored 1 for inactive, negative, or undesirable boundary and 6 for active, positive, or desirable boundary). Almost all of the adjective pairs have values higher than 3. The dimension Evaluation is associated with the contrasting adjectives: good–bad, helpful–unhelpful, nice–awful, and favorable–unfavorable. Its mean value was 5.2 (SD = .8). Items that define the Potency dimension: strong–weak, powerful–powerless, deep–shallow, and scientific–artistic obtained mean value of 5.1 (SD = .7). Activity scales refer to the extent to which the HD is associated with action and its value was 3.7 (SD = .8) and it is harder to interpret. Hence, without doubt, teachers recognize the value of the HD as a tool to develop their own research.

<table>
<tr><td colspan="3">TITLE: Alternative conceptions about chemical bonding</td><td>Pts</td></tr>
<tr><td colspan="3">FACTS: The source of difficulty to understand chemical bonding lies in students' alternative conceptions (Herrera, 2005). Different models of conceptual change give way to theoretical proposals to understand how alternative conceptions can be transformed into conceptions closer to the actual scientific understanding (Bello, 2007). All these models underscore the need to know students' alternative conceptions to be able to act in consequence (Rodríguez-Moneo, 1999). Designing teaching and learning sequences (TLS) has been pointed out as a recent and fortunate trend in science teaching (Campanario et al, 1999), especially when they are accompanied by strategies that foster minor changes in intermediate stages and not only major changes at the final stages of conceptual change (Thagard, 1992). According to constructivist models for science teaching conceptual change should be the final goal of science teaching and not its everyday method (Pozo, 1997).</td><td>3</td></tr>
<tr><td colspan="3">QUESTION: Which is the effect of a TLS designed using a constructivist approach (Moreira, 1999) in students' alternative conceptions about chemical bonding in two different groups of students of different high-school systems?</td><td>3</td></tr>
<tr><td colspan="2">CONCEPTS</td><td rowspan="2">METHODOLOGY
.</td><td rowspan="2">0</td></tr>
<tr><td>SCIENTIFIC</td><td>PEDAGOGICAL</td></tr>
<tr><td>Applications: Chemical bonding is a very important concept to explain properties of matter. It is also fundamental to predict the preparation of new compounds and materials.</td><td>Applications: Conceptual change models can be used to design more efficient TLS that aim to develop lasting learning.</td><td>Data collection: A diagnosis questionnaire was applied in two groups: (A) a group in the fifth year of ENP and (B) a group of first semester in CCH in two different moments: (I) prior to the implementation of the TLS and (II) at the end of the TLS. Given the space available we present only the results related to chemical bonding conceptions</td><td>3</td></tr>
<tr><td>Language:

Atoms, electrons, ions, chemical bonding, electromagnetic interactions , properties and behavior of matter, structure of matter, ionic structures, molecules, metals</td><td>Language:

Teaching and learning sequence, alternative conceptions, radical conceptual change, minor conceptual change, significative learning, constructivist approach.</td><td>Data processing:
<table>
<tr><td rowspan="3">Categories</td><td colspan="4">Percentages</td></tr>
<tr><td colspan="2">Group A</td><td colspan="2">Group B</td></tr>
<tr><td>I</td><td>II</td><td>I</td><td>II</td></tr>
<tr><td>Chemical bonding is a model</td><td>34%</td><td>58%</td><td>4%</td><td>55%</td></tr>
<tr><td>Chemical bonding as a reality</td><td>16%</td><td>24%</td><td>8%</td><td>4%</td></tr>
<tr><td>Chemical bonding as a model and a reality</td><td>45%</td><td>17%</td><td>88%</td><td>41%</td></tr>
<tr><td>Other option</td><td>5%</td><td>0%</td><td>0%</td><td>0%</td></tr>
</table></td><td>3</td></tr>
<tr><td>Models:

Unified model for chemical bonding with three different approaches: ionic,</td><td>Models:

Teaching and learning sequences (Sánchez & Valcárcel 1993), Conceptual</td><td>Conclusion:

In the first moment almost all students had a combined notion of chemical bonding as a model and a reality, with</td><td>3</td></tr>
</table>

Figure 1. HD about conceptions of chemical bonding.

covalent and metallic.	change model (Thagard, 1992), Ausubel's constructivist perspective of significative learning (1978).	difficulties to distinguish both. In the second moment there was a change because for both groups the majority of students situated chemical bonding in the category of model.	
ANSWER: Changes in chemical bonding showed by students are considered minor conceptual changes according to Thagard's conceptual change model (1992) because they imply a revision of students' beliefs in agreement with the TLS and the 'significative learning' theory (Moreira, 1999) which imply the modification of a secondary trait to be able to define chemical bonding as a model. A first effect of the TLS designed as a constructivist approach to chemical bonding lies in the fact that a greater percentage of students achieved a minor conceptual change. It is expected that such minor changes lead to a radical conceptual change about chemical bonding.			2
REFERENCES: (Ausubel, 1978). (Bello, 2007); (Campanario et al, 1999): (Herrera, 2005); (Moreira, 1999); (Pozo, 1997); (Rodríguez-Moneo, 1999); (Sánchez & Valcárcel 1993); (Thagard, 1992).			3
Self assessment (addition of all points)			20/ 21

Figure 1. (*Continued*)

Table 2. Results of the semantic differential scale.

Adjectives		Group 1		Group 2		Average	
Inactive, negative, or undesirable boundary (1)	Active, positive, or desirable boundary (6)	Intensity average	SD	Intensity average	SD	Intensity average	SD
Bad	Good	5	1.8	5.3	1	5.2	1.4
Passive	Active	5.8	.4	4.5	1	5.2	.7
Weak	Strong	5.4	.5	4.5	.6	5.0	.6
Boring	Exciting	4.5	.8	4	0	4.3	.4
Unhelpful	Helpful	6	.0	5.3	1	5.7	.5
Powerless	Powerful	5.5	.5	4.5	.6	5	.6
Shallow	Deep	5.8	.4	4.8	1	5.3	.7
Awful	Nice	4.8	.7	4.5	.6	4.7	.7
Difficult	Easy	1.8	1.2	2.8	1	2.3	1.1
Artistic	Scientific	5	.6	5	.8	5	.7
Slow	Fast	3.2	1.3	3	.8	3.1	1.1
Unfavorable	Favorable	5.3	.5	5.3	.5	5.3	.5
	Total average	4.9	.7	4.4	.7	4.7	.7

Teachers' reflections and opinions on the use of the HD

Four out of five teachers in the second group (G2) answered the questionnaire. We quote some responses from the teachers in order to illustrate teachers' perceptions on the usefulness and difficulties of using the HD for formative assessment.

Regarding usefulness of the HD and its relation to the development of their research project:

> It helped me focus the subject of my dissertation and find a model that helps me develop the teaching intervention. (T1)

> It is very useful. At the end I realized how much it helped to restructure my work. I had not figured out [prior to developing the heuristic diagram] how brashy my work was. (T3)

As for the difficulties, some of teachers' answers:

> In the beginning it was hard, I had never heard the word [heuristic diagram] and I thought it was going to be very difficult (…) Understanding all the items in the heuristic diagram is not that straightforward. (T1)

> The truth is I think it is difficult, especially the section where the key words [the left part of the diagram, related to concepts] are because I was confused between the thesis and my project (…) it was hard to come up with the first question. (T3)

From this brief analysis, it is possible to state that, overall, teachers find the HD is a useful tool in the development of their research projects and, in some cases, regret it is introduced late into their research process. It is also possible to note that the 'left section' of the diagram still presents important challenges to teachers that need to be addressed.

Conclusions and directions for further research

Helping teachers become researchers and reflective practitioners is not an easy task as has been shown in a number of different programs for teachers' professional development. The use of a HD that explicitly considers the dynamical nature of knowledge construction and the relation between theoretical stances and methodological approaches to research, and can be used to provide a clear feedback, seems to be a very useful tool to formatively assess student teachers as they grapple with the difficulties and nuances involved in research.

Cochran-Smith et al. (2009) have recognized that teachers' strong inquiry papers have some kind of 'theoretical vision' that links a precise intervention with general understandings on teaching and learning. The use of the HD somehow obliges teachers to identify their theoretical stance. In this sense, the HD is an improvement of Gowin's Vee because it aids in clarifying the conceptual side (applications, language, and models) in two dimensions (scientific and pedagogical) related to educational research.

We have presented a brief analysis of how teachers develop different aspects of the HD that point to the fact that it is indeed a simple and reliable tool for formative assessment because it improves teachers' research skills such as asking questions, recognizing concepts involved in research, and providing better (more complete) answers for those questions. We are well aware that such changes in teachers' formulations of their research project can have multiple sources and cannot be attributed only to the use of the HD. However, the positive opinions teachers express about it can let us point out that it is, at least, very relevant in bringing about such changes.

Additionally, the use of a self-assessment rubric allowed teachers to state more and better relations between the question (based on explicit facts) and the answer, the conceptual and the methodological part. Hattie (2009) recently reported the students' estimates of their own performance as the single most important factor related with achievement. Through the use of the HD and their self-assessment rubric, teachers gain a better insight into what is expected of them when doing research through iterative cycles of constructing diagrams, receiving feedback, and perform self-assessments.

The use of the HD as a formative assessment tools presents limitations such as the amount of time and engagement required from the teacher educator. Also, teachers need to learn how to make the first HD before they can begin to see its usefulness and this is not always a straightforward process.

Many questions remain to be explored for future research. For example, we could trace if (and it what ways) the completion of the HD actually shapes the dissertation. We could also look at the different ways in which sharing the diagram between peers allows for the each teachers' project advancement. Most importantly, we are now concerned with research concerning the development of students' pedagogical content knowledge in relation with the HD.

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Appendix: Instructions for completing a HD and scoring rubric

Title: (refers to the subject of research)		Pts
Facts: (this refers to information obtained and/or observations about something happening in the world that leads us to ask a question. Preferably should identify several of them)		
Question: (statement of an inquiry focusing on the facts. We must make sure that there is only one question)		
Concepts	*Methodology*	0
Applications (refers to applications for the issue under investigation)	*Data collection* (this refers to what we do to obtain the relevant information to answer the question. It should be pointed and detailed)	
Language (refers to the terms we need to know to answer the questions)	*Data processing* (refers to data management and results in tables, charts, diagrams, etc. which summarize the data obtained)	
Models (this refers to the model used to give the answer to the question. It may be scientific, economic, social, etc. For example, Lewis' atomic model, or Arrhenius' acid–base model, or market model, or constructivist learning model, etc.)	*Conclusion* (this refers only to that obtained from the processed data)	
Answer: (refers to the explanation that answers the question by bringing together the concepts and methodology's conclusion)		
References: (this refers to books, magazine articles, websites, etc., consulted and used in every part of the investigation)		
Self-assessment (addition of all points) (you need to score all the points collected and compared against possible points)		

Points	Characteristics
Facts	
0	No facts
1	Some facts are recognized
2	Facts are recognized and some concepts
3	Facts and concepts are recognized and also some methodological aspects
Question	
0	No question
1	There is a question related (supported) with facts
2	There is a question related (supported) with facts that includes concepts
3	There is a question related (supported) with facts that includes concepts and suggests some methodological aspects
Methodology	
0	No methodology
1	There is a procedure that allows data collection
2	Data processing (tables and graphics)
3	A conclusion has obtained through data processing
Concepts	
0	No concepts
1	Applications are identified
2	Applications and language are identified
3	

(*Continued*)

Appendix. (*Continued*)

Points	Characteristics
	Applications and language are identified and also models capable to explain the question
Answer	
0	No answer
1	Answer is quite similar to methodology's conclusion
2	Answer besides methodology's conclusion includes facts
3	Answer besides methodology's conclusion includes facts and concepts (models particularly)
References	
0	No references
1	There are references related only to facts, concepts, or methodology
2	There are references related to facts and concepts or methodology
3	There are references related to facts concepts and methodology