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# Mathematics and Physics Dialogic Gatherings: Fostering Critical Thinking Among Adult Learners

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*This paper discusses the effectiveness of dialogic learning as an adults' learning theory. It specifically focuses on how Mathematics and Physics Dialogic Gatherings (M&PDG) can enhance the critical thinking of adult learners and hence develop their learning in both topics. Two studies were set where the participants engaged in dialogic reading activity reading classics in mathematics or physics. The former study took place in Barcelona, Spain and involved adult women of above 40-years-old with low literacy skills engaging in mathematics. The latter took place in Kendal, UK and involved two groups of adult A Level students, one studying Psychology and the other Physics. Although the samples were extremely diverse, the results demonstrated that classical readings can significantly improve critical thinking and dialogic talk in all groups and provide the potential to create further learning opportunities.*

*Keywords: Dialogic learning, adult scientific literacy, gatherings.*

## Introduction

Dialogic learning has been one of the main approaches to adults' learning theories in the last decades (Flecha, 2000). This approach suggests that adults are self-responsible of their own learning. They become active agents, creating social spaces for learning, drawing on solidarity and social interactions. In order for adults to be active in their learning and express themselves, they must use processes that promote their way of thinking, understanding and their ability to reason; in other words, they must develop their critical thinking (as defined by the Foundation for Critical Thinking, 2017). The aim of this paper is to discuss Mathematics and Physics Dialogic Gatherings (M&PDG) as learning spaces for adults to develop their learning in both topics. Dialogic gatherings were originally implemented by Flecha in La Verneda Adult School, in Barcelona, in the late 1970s. In 1978, a group of people asked for popular education for adults and occupied a public building to offer literacy courses for adults who never had the opportunity to attend school. Drawing on Freire's work (who also visited the school several times), the adults participating in La Verneda Adult School created a democratic popular movement of education based on the principles of dialogic learning (Flecha, 2000). M&PDG are part of this initiative (Díez-Palomar & Cabré 2015, Díez-Palomar, 2017). In the following sections, we will introduce the theoretical framework, the methods used in the research reported here, and the main findings, for further discussion.

## Theoretical framework

According to Flecha (2000), learning is framed by seven principles: egalitarian dialogue, cultural intelligence, solidarity, transformation, the creation of meaning, instrumental dimension of learning, and equality of the differences. Dialogic gatherings are spaces where all these seven principles are evident. Flecha coined the term "dialogic literary gatherings" (DLG) in the late 1970s. He created the first DLG in Barcelona, with a group of non-academic women, most of them barely literate,

drawing on debates between some of the most outstanding scholars in adult education and social sciences at that moment, such as Freire or Habermas. Freire (1970) believed that learning matters because individuals discover that through learning they can make and remake themselves because they realize that they are beings capable of knowing. Learning for individuals is a practice of freedom. We can resist oppression and transform situations of domination, such as the lack of schooling, for example. Habermas (2001) also assumed understanding as a universal ability of human beings. In his *Pragmatics of Social Interaction*, he claims that meaning and understanding are two categories eminently human. Individuals develop their understanding through social interaction, sharing repertoires of meaning embedded in particular actions denoted by linguistic or semiotic signs (Habermas, 2001). Drawing on this idea, Flecha (2000) states that all individuals may be able to develop understanding (learn) using social interaction as a form of scaffolding. The DLG is defined as learning spaces where a) adult learners with low literacy skills participate, b) the readings are universal literature classics, and c) the process is based on dialogic learning (Puigvert, Sordé, & Soler, 2000). The DLG become spaces where individuals participate, interact, and share meanings around particular readings / words/concepts. The DLG became one of the successful educational actions validated in the research project *INCLUD-ED. Strategies for inclusion and social cohesion from education in Europe* (2006-2011).

Drawing on this background, La Verneda Adult School developed the Mathematics Dialogic Gatherings (MDG) using classic readings in mathematics to conduct the gatherings (Díez-Palomar, 2017). The research discussed in this paper starts with this experience and extends the MDG to science (Physics). The second author of this paper used this approach to create PDG in the UK, drawing on the principles of DLG (Soler, 2004, 2016).

## **Methodology**

### **The research question**

In this paper, we discuss some of the main findings from two independent studies focused in the same research question: “Can mathematics and physics classical readings promote the development of critical thinking of adult learners?”.

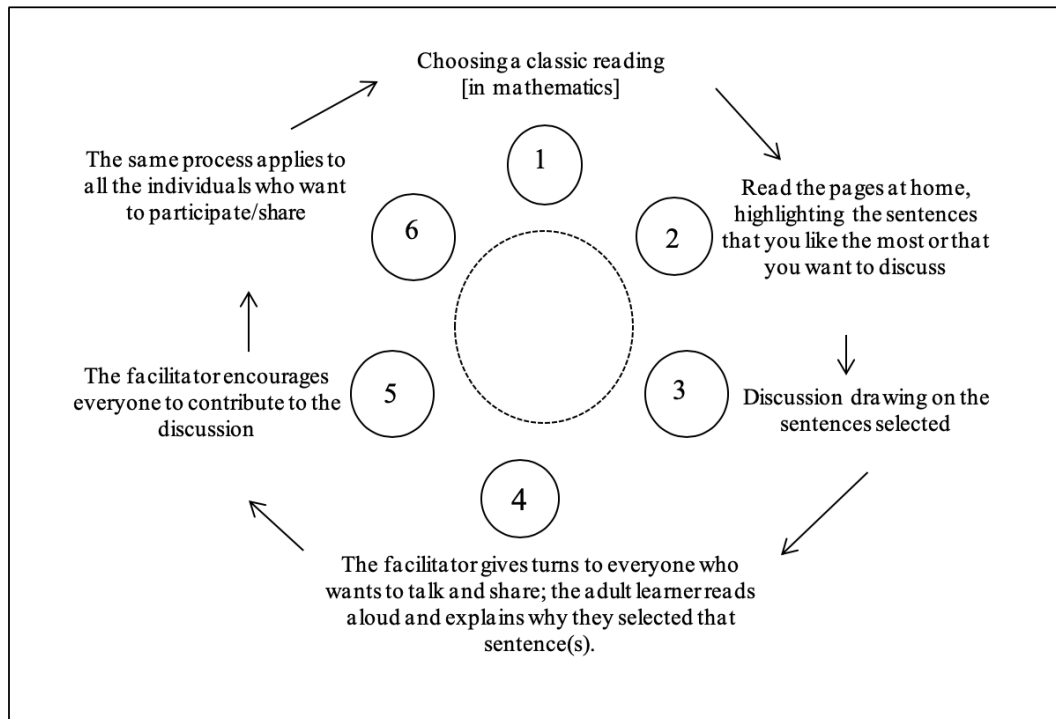
### **The setting and participants**

The first study reported in this paper was held in Barcelona (Spain). The setting for the study was an adult school placed in a working-class neighbourhood in Barcelona, Spain. Data was collected from May to June 2016 (seven sessions). Participants included six women between 40-years-old and over seventy-years-old, with low literacy skills. The second study discussed in this paper was conducted in Kendal College, Cumbria, in the United Kingdom. Data was collected during the last semester of the academic year 2016-2017. It involved two groups of A Level students, male and female: group PSY, who studied psychology and group PHY, who studied physics.

### **Research design**

In both studies, we created Dialogic Gatherings. These gatherings are spaces in which participants engage in dialogic reading activity involving classic texts in mathematics or science. Participants are the ones choosing the readings. The book selected for the first study was *Historia de las matemáticas*, the Spanish translation Jean-Paul Collette (1979) book *Histoire des Mathématiques*.

For the second study, the reading selected was *Dialogue Concerning the Two Chief World Systems*, by Galileo Galilei (1632). In both cases, we used the methodology of the DLG created by Flecha (see Figure 1).



**Figure 1. Scheme of how a M&PDG works (Díez-Palomar, 2017)**

## Results

The participants in the Mathematics Dialogic Gatherings (MDG) engaged from the very beginning in mathematical discussions around the history of mathematics. The six women seemed comfortable talking about the first traces of mathematics in the Palaeolithic Era, the mathematics used by the Babylonians, the contributions made by the people living in ancient Egypt, the mathematics formalized by the Greeks, etc. Drawing on the description of how humankind developed counting, grouping and the idea of number as the strategy to keep track of cattle, crop, the six women discussed such notions as number system, algorithm, unit of measure, value, equivalence, and so forth. They related some of these concepts with their everyday life. For instance, when discussing the concept of the base of a number system, they rooted their arguments in their previous knowledge about using different coins whose value is defined by groupings in base 1, 5 or 10. Their knowledge about *duros* (a coin equivalent to 5 pesetas in the old Spanish currency) facilitated their understanding about ancient number systems which a base different from the Hindu Arabic numbers that we use nowadays. Jean-Paul Collette mentions in the first chapter of his book that a bone was found in the Czech Republic with some tally marks carved in groups of approximately 30. According to the experts, it could be a moon calendar. Interestingly, one of the women in the group highlighted this excerpt of the book because she stated: "I remember that I read somewhere that some people think that those marks correspond to the menstruation cycle." Then, a further discussion about mathematics and human biology started, connecting mathematics to gender issues. During the sessions, many other issues arose: Why the Romans didn't have the zero in their number

system?, How to translate quantity from one unit of measure to another?, and What strategies are best in problem solving?

For every topic, the participants in the MDG used their own personal background to, in Flecha's (2000) terms, "create meaning with the mathematical content. The book presented many symbols and codes (numerals, formulas, graphical and visual representations), that usually are abstract representations of real phenomena. Data suggest that women were able to create a zone of proximal development where everyone was free to contribute with their piece of knowledge drawing on their own experiences. According to Hutchins (2000) this can be defined as episodes of distributed cognition. That was the case when developing an understanding an ancient algorithm for multiplication presented by Jean-Paul Collette (1985) in his book.

In the same vein, the Physics Dialogic Gatherings project further examined participants' progress with respect to their background knowledge, in a different setting.

During the first sessions, the psychology group got involved in discussions in a descriptive and philosophical manner. They felt more confident to discuss philosophical ideas, such as the definition of *perfection* in the text, and they tend to avoid or ignore any scientific or mathematical part of the book. An example from a participant:

"If I were in this conversation I would question the definition of perfect and what is exactly they are trying to achieve by defining these principles? What are they going to achieve if they finally define that the Earth is perfect? What does perfect mean?"

They often exchanged information directly quoting from the text without showing any understanding of the ideas transmitted. For example:

"Pythagoras says it's defined by beginning, middle and end, but others are saying perfect is how you form the body; the length, and thickness."

They did not challenge the obvious. They preferred to agree with that. Direct quotation from the text:

"They say about the lines that the straight line is the shorter one and obviously you can have many other lines. I agree with that."

During the later sessions, they felt confident to discuss science too, starting with simple arguments and poor terminology. Their dialogic skills evolved with time when they felt the need to use definitions and self-created terminology. They created their own terms when the lack of scientific knowledge did not help.

"I think it depends what fast is. In our situation our fast is like steady and we have air-resistance and when it reaches terminal velocity, it will be like balanced. Whereas if you are in a car and it speeds up and in fact you are in control of the fastness, you will just accelerate until you reach where you want to go and then you will put another force acting into it because you want to slow it down. So it depends on which fast it is acting on."

They could formulate arguments where critical thinking was evident. As they were feeling more comfortable, they progressed to using scientific terminology, which emerged either from the text or

from prior knowledge that they had not used for a long time, but they recovered it for the sake of their argument.

“So, say you have a forward motion, velocity and then you have the air resistance and gravity. They would balance out in a way that the one motion is still more than the others because it still moving forward, because if the others weren’t there it wouldn’t have to speed up.”

Their critical thinking was developing, and they were more involved in discussing their ideas in a dialogic manner, even if these ideas could be wrong.

“If the plane is tilted, the ball starts moving and speeds up until it reaches towards the end. And then reaches a flat surface again. So yes, I agree with that. There has to be some kind of limit, because... I don’t know... It can’t just speed up, speed up, speed up. It has to be some kind of limit.”

Towards the final sessions, they were able to combine physics and philosophy into their arguments, which triggered further discussions and carried forward their learning skills.

“It’s got to have some purpose to move. A body which is not moving, will move if it has a purpose.”

The physics group seemed more open to disputes and reasoning than the psychology group, possibly because they considered the text to be more on their area of expertise. They approached the ideas presented with scepticism and doubt, rather than with unquestioning acceptance, which already indicates a level of critical thinking (Scriven, 1987). In the early sessions, the group was dealing with the texts purely scientifically, ignoring any philosophical quotations in contrast to the psychology group. The physics group was seeking for proofs and they even performed their own in-class short experiments to prove a point.

“Salviati is saying that he doesn’t believe that 3 is necessarily more perfect than 4 or 2, and gives the example of legs on a chair or table. And I was wondering if it is harder to knock over a table with 3 legs or 4 legs, because with 2 legs obviously it is not stable.”

They employed their scientific background knowledge to explain the ideas presented in the reading.

“Triangle is the strongest shape in nature so I guess it may be stronger.”

“...because there are more ways where you can pass the center of gravity.”

At later sessions, the group was involved in philosophical critical thinking too. The engagement with the philosophical terms expanded their discussion away from the actual text and they were able to connect science with philosophy. Their critical thinking and dialogic talk development evolved to a point where they were disputing scientific methods that they had never disputed before. They questioned science and mathematics and they concluded that they had more trust in their senses than some scientific proofs.

“Does mathematics support or help science, do you believe things because you see them to be mathematically true or do you believe things because you see them to be physically true? What creates new knowledge?”

## Discussion

In 1976 Wood and his colleagues coined the term “scaffolding” as a metaphor to analyse how adults assist children when solving problems. They defined it as an action that “enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts” (Wood et al, 1976, p. 90). This concept moved forward the old Vygotskian notion of ZPD (Bruner, 1986). Cazden (1979) extended the concept from its original use in the context of dyadic adult-child interactions, to a study of teacher-student interactions in classroom settings. More recently, a special issue published in 2015 in the journal *ZDM Mathematics Education* (47,7) explored the interlink between this metaphor and the idea of dialogic teaching. Evidence suggest that dialogic teaching pushes forward to notion of scaffolding, since *dialogue* creates opportunities for participants to exchange and share knowledge from which create their own understandings. In this paper, we found evidence suggesting that this approach can also be used in the context of adults learning in both mathematics and physics.

Overall, the Mathematics and Physics Dialogic Gatherings project proved to be an enjoyable method for the teaching and learning of physics and mathematics. Data collected suggest that egalitarian dialogue can create opportunities for learning. The participants, drawing on their dialogic talk, created Vygotsky’s (1978) zones of proximal development where all participants contribute with their cognitive potential. Our results also confirm Hutchins’ (2000) notion of distributed cognition, since many times the different participants ended with a complete explanation of a particular notion, such as the uses of the zero in a number system, after sharing different pieces among them. The egalitarian dialogue, as defined by Flecha (2000), means that everyone has the same opportunity to share his/her previous knowledge throughout a dialogic process in which every participant shares arguments based on valid claims. The participants of the psychology and the physics groups as well as the mathematics group were able to make valid claims on the understanding of mathematical, scientific and philosophical concepts. This suggests that the critical thinking of both groups was significantly improved.

In addition, the results also reveal that using an egalitarian dialogue based on personal previous knowledge, adults were, in Freire’s terms, able to *read (and re-read) critically the world*. The different notions discussed during the sessions in both settings gained from this personal way to present them to the audience in the M&PDG. Linking them to personal situations in the everyday life appears to be a successful strategy to create meaning around the concepts discussed in the group. As Flecha (2000) states: “the creation of meaning is one of the more seminal principles of the Dialogic Learning theory since learning is strongly connected to motivation, as previous studies have largely demonstrated (Mehler & Bever, 1967)”. Freire narrates the case of a woman who learned to read and write by sending love letters to her husband. For this woman, the words acquired full meaning because they transmitted her feelings to her husband, who was far away. In a similar vein, for the women participating in the MDG recalling their memories about duros and pesetas was a way to make meaning to the idea of base in a number system. In this situation, grouping, which is an important component of numbers in number systems (as well as in the development of number sense), was fully understood by the six women participating in the MDG. They not only used the notion of grouping (base); they were also able to explain different algorithms to do mental calculation drawing on the use of grouping as a cognitive strategy to solve

particular cases of calculations (mainly addition and subtraction, and sometimes multiplication as well).

The research demonstrated that background knowledge is important to establish an egalitarian dialogue, in the sense that everyone uses their own repertoire of knowledge to participate in the dialogue. Although the two groups were very diverse in terms of background knowledge, they ended up in parallel ideas when combining mathematics, philosophy, and science. They approached the notions from a different perspective but somehow, they concluded in similar ways. Combining mathematics, science and philosophy opened new perspectives into their learning of physics and mathematics. In fact, results suggest that “heterogeneity” may be a successful component of M&PDGs. Without that heterogeneity, participants in the gatherings would not be able to introduce different examples to illustrate particular scientific or mathematical notions, making learning more depth and meaningful for everyone in the group. The Dialogic Gatherings method can, therefore, benefit heterogeneous groups, where people can learn from each other, taking advantage of the knowledge that everyone shares within the discussion. This is consistent with previous research in the educational arena (Flecha, 2000; Vygotsky, 1978; Wertsch, 1990).

Summarising, evidence suggests that classical readings and egalitarian dialogue could be an excellent method to improve critical thinking in mathematics and physics and have the potential to create further learning opportunities in classrooms.

## **Conclusions and further research**

In this paper, we have discussed how adults in two different settings (Barcelona and Cumbria) draw on their participation in the M&PDGs to develop their critical thinking around mathematics, science, and philosophy. Results suggest that adults use their own personal background to make meaning to the academic concepts in the books selected. Egalitarian dialogue mediates learning through a participatory process in which adults share their personal understanding of the topics discussed in the gathering. They use practical examples, drawing on their memories and looking for plausible explanations. In doing so, they acquire proficiency in using expert scientific and mathematical jargon. However, evidence reported here are limited since they belong to two single case studies. The sample is neither representative nor random. The examples introduced in this paper illustrate some intuitions about how adults, using classic readings in mathematics and science, can further learn and create a critical thinking aligned to what some authorities claim as being critical citizens in the rise of the 21<sup>st</sup> century. However, due to the limitation of the research design, more research is needed in order to generalize the benefits of the MP&DGs in supporting adult learners’ critical thinking, in other settings.

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