Science and investigation: teaching for sustainable learning for students with disabilities too

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ABSTRACT

In 2010 an experimental program was launched to see how teaching science in the spirit of "La main à la pâte" could be applied to the schooling of children with mental or physical disabilities. From 2010 to 2016 a group of 40 primary school teachers were involved in this program. Interviews with all these teachers and the analysis of specific days (called study days) have revealed a number of constants that highlight both the contributions of science teaching based on investigation as well as the difficulties. This 5-year experiment has enabled a number of teachers to train in science and resulted in new ideas to improve the training of teachers in science education.

KEYWORDS

Science, investigation, primary school, students with disabilities

RÉSUMÉ

En 2010 a débuté une expérimentation qui cherchait à voir dans quelle mesure faire faire des sciences dans l'esprit de « La main à la pâte » pouvait avoir un intérêt pour la scolarisation des enfants en situation de handicap moteur ou mental. Ainsi de 2010 à 2016 une quarantaine d'enseignants de l'enseignement primaire ont été impliqués dans cette expérimentation. Des entretiens avec tous ces enseignants et l'analyse des journées d'études annuelles ont permis de dégager un certain nombre

de constantes qui précisent non seulement les apports d'un enseignement des sciences fondé sur l'investigation mais aussi les difficultés rencontrées. Ces cinq années ont permis à un certain nombre d'enseignants de se former en science et donnent des idées pour améliorer des formations d'enseignants en sciences.

MOTS-CLÉS

Science, investigation, école primaire, élèves en situation de handicap

Introduction

International surveys like those of Patton, Palloway and Cronin (1990) show that students with special education needs receive very little education in science. The majority of those who do only have one hour of science per week. These courses are often taught with a transmissive approach with emphasis mainly on content and learning vocabulary. Several studies on mainstream teachers (e.g. Mitman, Mergendoller, Marcham & Parker, 1987) and on specialised teachers (e.g. Miller & Cawley, 1987) indicate that the vast majority only focus on presenting facts rather than methods of investigation and ways to find these facts.

Several studies recognize the positive aspect of learning science through inquiry and manipulative exercises (Bay, Staver, Bryan & Hale, 1992; Dalton, Morocco & Tivnan, 1997; McCarthy, 2005; Irving, Nti & Johnson, 2007), in particular for young disabled persons. Children seem particularly pleased and motivated during activities of this type (Scruggs, Mastropieri & Sullivan, 1994). Moreover, pupils with special education needs will be able to learn and better understand scientific concepts if teachers suggest that they are able to solve problems (Nolet & Tindal, 1993).

Which science education?

Inquiry-based science education is highly developed in the Anglo-Saxon world and there are many articles on the subject. In particular, Harlen (2012) and the site corresponding to the Fibonacci project as well as the article by Figdor & Decker (2018). In France, we have chosen the pedagogy recommended by "*La main à la pâte*" (Charpak et al., 1996), which, as one of the ten principles of *La main à la pâte* indicates, "*During their investigation, children argue and reason, pool and discuss their ideas and results, build their knowledge, hence a manipulative activity is not enough*". Students, with this approach, are active in their learning: they question results, propose solutions, make suggestions, even hypotheses, without any instigation from teachers and propose experimental protocols that they test themselves (Saltiel 2006; Worth, Duque & Saltiel, 2009). The students each have an experiment notebook in which they are invited to express their initial ideas, then to draw or sketch the imagined device, to report on the experiments carried out and finally to compare their results so as to arrive at a valid conclusion together, under teacher supervision and perfectly compatible with academic knowledge. With this approach, the child builds his own knowledge through his own reflections, discussion with his peers and practical manipulations.

Why science education for children with disabilities?

It may seem surprising to wish to introduce science education for these children. Regardless of their cognitive, behavioral or motor difficulties, they have far fewer hours of tuition than children without disabilities, mainly because of the required hours of care. Also, most of the time, teachers favor the teaching of French and Mathematics, because these two subjects are evaluated nationally in French schools. To the question: can inquiry-based science teaching play a decisive role with students in difficulty, Charpak, Léna and Quéré (2005), answer that this teaching "*has a very particular characteristic which is related to the existence of a third party object. [...] The relation to the third object that is so essential to the emotion that produces curiosity, may also be at the origin of the benefits that have been repeatedly reported to us during such science lessons on children with motor or mental disabilities; [...] wouldn't this relation to reality be beneficial, through a scientific approach based on the mediation of objects and sensitive phenomena, and help children locked in their handicap, to extract themselves from it?*". Scientific activities make it possible to approach the universal. Scientific facts exist and can be observed independently from the living conditions of the inhabitants of the Earth. The rules, laws, properties used to describe our environment are built outside the social and emotional life of each. If you drop a pen from a certain height, it falls ... whether you live in France, Brazil or Japan, whether you are from a well-off family or your father is unemployed, whether you are with or without disability.

Description of the project and methodology

Following a questioning of the French National Council of Disability (CNH) on the possibility of teaching natural sciences according to the pedagogy advocated by *La main à la pâte* for students with disabilities, a reflection was initiated. In November 2009, a study day was held with members of the Academy of sciences, the Inspectorate of National Education, INSHEA, members of *La main à la pâte* and Classroom Teachers for Inclusive Education (CLIS)[1]. It was decided to launch an experiment entitled

1 Today the CLIS (Classes of Inclusion School, installed in the premises of a primary school) were replaced by devices called ULIS (Localized Unit for School Inclusion). CLIS 1 welcomed students with cognitive or mental disorders, pervasive developmental disorders (autistic sphere), specific language disorders (dyslexia, dysphasia) or behavior. The CLIS 4 welcomed students with motor disabilities, dyspraxia disorders and motor disabilities associated with other disabilities

Handisciences during the 2010-2011 school year, relying on deliberately limited numbers of classes in CLIS 1 (major disorders of cognitive functions) and CLIS 4 (motor impairment). We did not address classes of deaf, visually impaired or blind students. During this exploratory year, eleven CLIS teachers practiced an inquiry-based science education from one of four sequences (three physics and one life and earth sciences) developed by the research teams, INSHEA and *La main à la pâte*. These sequences included experiments and, very often but not always, the realization of an object, such as an electric carousel for example.

Each sequence was built on the same model: the notional and methodological objectives for each session and for the entire sequence were specified; the vocabulary introduced during each session was listed; each session consisted of three essential phases (a questioning one, followed by a time for collective or individual reflection; a phase of experimentation and representation; a time for sharing, confrontation and synthesis of results); followed, whenever possible, by an evaluation sequence. Finally, each proposed sequence contained a small number of sessions (4 to 5), although it was specified that teachers could split each session in half, if the need arose. Each teacher was accompanied by a pedagog (trainer or pedagogical adviser) and aided by a scientist outside the classroom. Initial semi-directive interviews (before the completion of the sequence) and final (after the completion of the sequence) interviews, lasting between 1 hour and 1.5 hour, were conducted and recorded.

First-year results were particularly positive, hence the proposed protocol was reproduced and enriched in subsequent years. Indeed, as the vast majority of teachers involved wished to continue to participate in the project, having discovered the pleasure, the great interest, the motivation, the curiosity of their students as well as abilities which hadn't been suspected thanks to these science sequences. The contents of the interview grids have evolved over the years. In 2011-2012, teachers were asked to provide each student with an experiment notebook. Also at the end of this school year, the initial interview included, in addition to the usual questions, the following question: 'Can inquiry-based science education improve the written skills (texts, drawings, diagrams) of students in a disability situation?'. In the following years, the interview focused on other particular points such as the role and interest of the rituals, the evolution of pupils' writings, the role of error, the relations between pupils and the place of the pupil in the class group, the possible links with non-specialized classes.

All the interviews were transcribed and analyzed in order to prepare the study day which took place every year before the summer. The documents produced by the

(polyhandicap including intellectual disability). Thus, in CLIS 1, students with an average intellectual disability (35 <IQ <49) could be found if they were not associated with impaired abilities, a slight intellectual disability (50 <IQ <69) to impaired abilities. There are groups of equivalent students in Les Ulis, but their schooling is organized differently.

teachers, pupils' productions, short videos taken by teachers, the analysis of the interviews, as well as the works realized during the study days were analyzed according to the theory developed by Glaser and Strauss (1967). This has led to numerous qualitative results, both for students and teachers.

In June 2016, the fifth year of operation was achueved with forty two teachers involved and more than five hundred students, the majority in CLIS (1 and/or 4), the others in specialized centers (hospital, medical educational institutes, etc. ...). The majority of the children concerned have dys disorders, cognitive disabilities, behavioral disorders, autism or motor disabilities.

In 2016, the Inclusive Education Classes were replaced by ULIS, whose main objective is to promote the inclusion of students with disabilities in regular classes and to eliminate specialized classes. Although we continued to work in 2017 with a few teachers who were still working with all their students together all week, we interviewed all teachers in 2017 on this experiment.

Results

The interviews of the 42 teachers, as well as the six study days that took place each year, revealed a number of constants.

Pleasure and curiosity

All the teachers are unanimous: the children had a lot of fun doing science and developed their curiosity. We report here the words of the teachers. Thus MDC said "*the pleasure of doing is extremely important, especially since it entails learning in all fields*" and ED "*the participation in this experimentation has brought a lot of pleasure to the partners, children and adults*". CF "*Let's say there is always curiosity. Maybe it showed them that they could express it in class and that curiosity was not something forgotten or put aside*". AB points out: "*They were already curious, but they did not allow themselves to ask questions. There was a change of posture: before the student who questioned was the one who did not know, now the questioner is the one who wants to know or be sure of what he knows, check his own knowledge ... curiosity is more in their mind a sign of inadequacy. They understood that they had the right to express their ignorance and that they could ask questions*".

Interests of manipulation

When children manipulate, we can observe that they touch (for example silk fabrics, rough fabrics, etc.), look (their shadow, the bulb they managed to light ...), listen (the noise that causes the movement of a worm on a thin sheet of paper) and make movements. This was observed by a student from the Ecole Polytechnique who worked with CLIS teachers to accompany them. "*Teachers discovered that manipulation was a* *way to get into science education. Feeling, touching, seeing, allows a better understanding of the phenomena: these children in particular have even more need to manipulate in order to understand*". Likewise teachers E and A *report* "*With students with disabilities, it is important to manipulate. We cannot get them, unlike pupils without disability, to observe without manipulating*".

But we must remain vigilant and not be satisfied with 'doing': manipulation is necessary but not sufficient. During a study day, the teachers met and reflected on the interest of manipulation. Here is their conclusion:"*It is an entry that puts certain students at ease and values talents that are not immediately highlighted (or not detected at all) in an abstract, theoretical or more 'academic' activity; it can therefore be a major support in terms of the learning engine, the lever to give a student confidence, to enhance his or her skills, to make him want to progress and go further, even to provoke vocations or interest in specific fields of activity. It is an opportunity to encourage cooperation (eg assistance in a montage), tutoring, group work that enriches the proposals of each (if we stimulate the emulation that can create a group and encourage help within the group). It is a way of rebalancing an often prematurely abstract teaching. Students enjoy manipulating, they find meaning... Some students have not benefited in their educational environment from experiential discoveries (play with water, sand, materials, sensory experiences, make a cake, walk in the snow or in puddles...)*".

Work together and learn to cooperate

CLIS (1 and 4) are extremely heterogeneous classes. In the same group, there may be children between the ages of 6 and 12, readers and non-readers grouped together, who have a wide range of disabilities, such as motor function disorders (whose effects on learning vary from child to child, intellectual development delays, rare diseases, pervasive developmental disorders or specific learning). One of the consequences of this heterogeneity is the need to individualize the work; most of the time, teachers work in a dual situation with each student, which poses a problem in terms of collective life and integration. Indeed these children may think that life in society boils down to taking care of them individually and might feel rejected if the adult does not give them individual attention. Therefore, they may also have more difficulty than regular class students in listening to others, in accepting another point of view, especially if it differs from theirs. So we asked teachers to organize group work whenever possible, which they did. The report is conclusive: all teachers appreciated group activities and underlined its undeniable advantage.

In fact teachers put forward various methods of group work, as teacher AB explains: "*The science sessions are conducted with the whole group. There is a collective phase where everyone participates in the exchanges. Here there is emulation... Obliged to verbalize, to express their feelings, some dare to express themselves, to ask questions, to question themselves. Taking into account the opinion of everyone forces the more talkative to listen to oth-*

ers, the more laid back to talk". Teachers share the impact of this work: EA states that "*Group work is beneficial: it makes students want to help each other, confront their difficulties and exchange on them*". SG reports "*There is also a pleasure component, the pleasure of working, of thinking together that results inevitably in the founding of a group*". EA says: "*The students exchanged very little at the beginning of the year, spoke very little in class. A typical pupil did not speak because being dysphasic, it was difficult for him. Now we realize that he interacts with others that he dares*".

In addition to changing relationships and listening between students, it was noted that their place and role in the group had changed. SG remarks: "*Together, they were thinking and were good working together. Everyone had their place and it helped them to work better together on other things. It was easier because it was an area that did not directly affect their disorder, it was lighter for them and so they worked more together, they had confidence in themselves and wanted to talk to each other*". SB says, "*There have been changes in attitudes. I found that some who were... leaders because of their character within the group, have changed places. Some who were shy speaking proved to have good ideas, to be good handymen and could occupy a little more space than usual and play a more decisive role in small research groups of 3 or 4 students... So there was an exchange of roles within groups*". CdSM, which teaches autistic people, confirms "*I think that some students may be more comfortable than usual, and suddenly become more motivated and self-confident, because certain strengths are revealed that are not inevitably very visible in written work. This boosts their confidence and suddenly they are more present or participate more in everything else*". AD says: "*Here, to accept that another student does not necessarily think like oneself, that he does not have the same idea, that does not mean that one is better than the other, that one is wrong, and little by little, accept the other person's point of view, to see if what one thought can be questioned, without losing face, etc. .. I think this is constructive. Thus, to try and leave traces, to compare them with those of others, to learn to think collectively, to look for ...*" are skills that are slowly developing.

Towards a construction of reasoning

Reasoning supposes that one has the faculty to analyze the real, to perceive the relationships between things, the relations between objects present or not, to understand facts. Before understanding facts, it is important that children manage to make sense of the proposed activities. Thus teacher JH relates: "*they really seemed to say to themselves: ah yes there is a question, because at the beginning, the meaning of the question was not at all self-evident*". Thanks in part to the manipulation and practice of routine assignments, and despite problems with memorization, students remember questions asked from one session to the next. Thus AD puts forward the interest of sciences which allows its pupils to "*follow the thread of what one is looking for, of what one is doing*".

Any questioning of the world leads children to observe an object or a phenomenon.

Observation is not always easy and is learned, as noted by AD: "*What strikes me most is perhaps their greater ability to observe, namely to look at and know how to say what they see*". Similarly, TD, in the sequence on earthworms, states: "*we can see in their graphical representations an evolution between the initial representations and the following ones: rings, streaks appear ... the pupils have learned to observe and to concentrate on the object*".

Many children have been spontaneously connected to their daily lives. For example, SB says, "*It was obvious, on the subject of motion transmission... When we looked at the gears and the belt drive, a student said he took out a car that he had at home. Well, there are gears, like those at school, I did not know, I would never have thought*". EB, as part of an activity on the buoyancy of objects, states: "*Making a connection with their personal experience is something that I had not seen before and which often seems difficult for these students; while in this context of activities around 'flows or floats' where one tests the buoyancy of various objects, a student thought of fountains at the bottom of which one throws coins and another made connections with his ball games. When we play ball with dad, the ball stays on the water*". Some teachers have discovered in their students a reasoning ability: EB remarks: "*I discovered them during the sessions, I think I have underestimated their reasoning abilities*". MB adds: "*The pleasure of manipulation is extremely important, facilitating learning skills in all areas: ease of expression, improvement of oral expression, ability to explain things, to make assumptions, to reason too. I think they are improving. This enabled me to get to know some students better, especially one particular student in huge difficulty in all subjects. I realized that he had a reasoning capacity that was present and that I had not seen elsewhere*".

One of the important problems that often arises when one is doing experimental science concerns the methodology and also whether or not the result obtained is valid. In particular, it is well known that if we want to test one factor (and only one), we must vary one parameter at a time, all the others to be kept constant. This is not easy as indicated by many works including those of Flandé (2003). The sequence 'water and plants' has the particularity of dealing with this problem. It is constructed in the form of a series of sessions with exactly the same course, and proposes an experimental protocol studying only one parameter. So SB says "*a sequence like water and plants requires such experimental rigor to really arrive at an indisputable conclusion that it was very formative. The students who have been there for three years and who have experienced this sequence have acquired a rigor, a method of working during the construction of an experimental protocol*".

Acquiring knowledge

All teachers report that their students have acquired new knowledge. This point of view is unanimous. Let us quote first of all the statement of an educational consultant who followed a middle school class from Toulouse that worked on electricity "*I am amazed to see that these students know much more about the closed circuit than ordinary*

5th graders". SB completes: "*They have acquired knowledge about electricity that is not just limited to the classroom, because they can share with others and transfer it to what they know about electricity in the home*". "*As the class is open*", says FB, "*people pass by, students from other classes come and see the terrarium. So my students can explain what's in the terrarium, open it up to show them, using the correct terms. I think it makes them feel good to be the ones who know*". Another teacher conducted a test two months after the sequence and was able to verify that the children had remembered what they had done and learned two months before, which was not the case in other work areas in the classroom.

La main à la pâte strongly emphasizes the link between science and language. Although some children have some difficulty in writing, it has been possible to develop vocabulary, as MB says: "*Orally, I notice an evolution. They are better able to analyze and explain what they have done ... some children who are inarticulate at certain times, have made efforts to be understood by others and indeed used a suitable vocabulary*". SB, whose students were readers, proceeded as follows: "*At the very beginning, when we started talking about electricity with the carousel in their sights, many spoke very often, with lots of words like 'thing' or 'that' or 'there' 'here'... Later, when we started using technical vocabulary to designate wires, motors, battery, terminals, axis, trays, supports etc ... they spoke less, because they had not mastered the vocabulary yet and I imposed the use of correct terminology. We had a short period of difficulty in expression, and then, when the vocabulary began to set in (axis, support, terminal, battery ...) we found participation in oral and even in writing as important as previously, but with a much greater precision in language this time*".

The written traces

Notebook

Here, we must remember that in these classes, all students are heterogeneous. Indeed, we often find in the same class children whose age varies from 7 to 12, readers, non-readers, children who can write, others who cannot, huge differences in learning skills, etc.

However, in the second year, given the importance *La main à la pâte* ascribes to writing and fluency in language, we imposed that every child should have a science or experiment notebook as part of the project, which was not the case in all classes. At the same time, we thought we would acquire valuable information about the possibilities of these children in terms of drawings, diagrams and writing. All but two teachers provided each child with a notebook (or pocketbook) from the beginning of the sequence. The two teachers who had not provided a notebook at the start gathered the pupil's production on individual sheets of paper: "*I did not have a notebook to begin with, so they made their drawings on loose sheets that were numbered as you go. I collected them all and stored them ... then made little notebooks for each student*". Subsequently, all students from classes engaged in the project had a science notebook, a notebook to which they were attached. "*It has been a pleasure to receive this new notebook*" (SG); "*At first they found it a little strange, after they got the hang of it quickly enough*" (FB); "*There are pupils who flip through it every time they study electricity. I do not ask them to take it. On the hypotheses, there are plenty who will consult it*" (ID); "*This notebook is very important to them because it immediately refers to the theme we are working on. ... the experiment notebook is a landmark for them*" (EA); "*It was called 'the researcher's notebook' and they are very proud of it ... they do not want to lend it, they want to keep it*" (NK); "*They are attached to the material side. It's their notebook*" (A and E). "*They were very happy to receive this experiment notebook, they invested in it very well ... there was the playful side, different from usual, so they were very enthusiastic*" (PS).

The status of error and intermediate writings

The vast majority of teachers think that we learn by making mistakes. Let us quote SB which sums up what all teachers think: "*It seemed to me interesting to show them that, to learn, it is necessary to make mistakes. It is written above the door of the class, but it is an approach that we try to apply to all learning, even outside science. And it seemed interesting every time, to redo what had been done before, to see the assumptions, the observations, the conclusions, whether they are right or wrong, and to show precisely that it is through trial and error that we come to question. Therefore, if we obtained a result that was different from what we had imagined, jostling our suppositions a little bit, it was this gap between the hypothesis and the result, which (through the mistake I made and the result that contradicts it) enabled learning. It seemed interesting to me, both for knowledge and methodology in science, but also for self-confidence, to say to myself, 'Well last time, we were indeed wrong but ...' this is not experienced by students as a failure ... That's it! It's not a drama, I was wrong because I had a representation that was wrong and finally it was the experiment that showed me that my representation was wrong but thanks to that, I was able to think and put something in place, an experiment, a device, a circuit ... to learn something, and not to be taken in next time*". EA says again: "*What I'm trying to tell them too is that we all make mistakes, I try to play down the mistake. Sciences make it possible to give error a status: one builds on that. We see concretely that a hypothesis can be false, which encourages them to take risks, to start*". A great many similar statements can be found in the testimonies. All convene that error is part of learning.

But do students and teachers agree that there are incorrect writings and drawings in the notebook? Some teachers specify that, in the notebook, there must be what a teacher calls the 'unfolding': "*we try to end every session with a kind of conclusion that answers the question and which is quite simple in the wording*". During a study day, teachers who worked on the content of the notebook, said: "*There are also tests, errors, a set of attempts. When work is done ahead with pupils on the status of error, this avoids interruptions in the students' approach*".

However, it is not always easy to accept this type of 'unfolding', that is to say to have, for example, in the booklet incorrect drawings. So, some teachers told us that they asked the children to make individual drawings on loose sheets, then to build collectively 'THE DRAWING' that best represented the experiment to be put in the notebook. Others encountered problems with students. In this instance, we quote the following excerpts from teacher interviews when asked whether or not the students had used their notebook or not. "*Yes, they were aware that any experiment was recorded in the experiment notebook. Some students did not necessarily want to put the first trace in this notebook because for them it was a finished product, like a lesson book*". Indeed, it is traditional in French classes that students have two notebooks: a notebook of the day (where in principle everything is correct) and a draft notebook. Some students, after experimentation and reflection, thought that it was necessary to put in the notebook what was successful in order to show what they knew how to do and not what they had learned through the process, their errors and difficulties.

Rituals and adaptations

All teachers are unanimous: their students need not only rituals to help them learn but also time. Thus some teachers were led to do one of the sessions proposed in two or even three sessions.

Regarding rituals, during a study day, a working group came to the following conclusions: "*The (or) start-of-session ritual(s) is important because it allows to organize the time and the space. Often it is time to recall the content of the previous session, sometimes based on the notebook. During the activity, the rituals were found mainly in the setting up of several roles with responsibilities (team leader, table, time...). An end-of-session ritual allowed students to indicate their opinion orally on the work done first from a personal point of view (did you like it or not, why?) And then concerning their learning. To sum up, rituals secure and channel. They save time and give time references, which limits the anxieties of some students. On the other hand, they allow conflicts to be managed by their structuring and soothing effect*".

Virtually all teachers use posters (sometimes in the form of flipcharts), posters made by the teacher or by students and teacher, for example: "*there was always a written record, either on the board when we wanted to continue the next day, posters with photos which students were regularly requested to contribute*" (SG); "*We posted the displays from one session to the next, so it was essentially drawings. When we had agreed on a diagram, I drew it on paper*" (FB); "*We always had the flipchart in a corner of the classroom, which kept track of the previous session and the sessions before*" (AD); "*I offered them writings in the form of tables, small texts summarizing the knowledge acquired, writings in the form of pictograms or labels with one or two words to help the structuring of thought, different displays depending on whether they were intended to summarize knowledge or to provide support and aid the pursuit of scientific reasoning*" (N); "*During the sessions, we even noted what the* *students said, their observations, their reflections, and they recorded them live. We kept the displays of what the students told us*" (P & E). Some used vocabulary cards to reactivate students' memories and revive their activity.

Links with students in regular classes

Most teachers have found that this teaching has been instrumental in increasing students' confidence and self-esteem. This has been particularly evident in classes in primary schools, as opposed to classes in institutes or hospitals. However a number of teachers have ensured that their students interact with classes of students without disabilities.

Thus, SB had each of his students play an electric carousel. When the sequence was over, the carousels were shown to the whole school and students without disabilities also wanted to build a carousel. It was decided that the students of the CLIS would share their knowledge and skills by accompanying the students of a class CM1 (K-4th grade) in the realization of a carousel. The CLIS students became the guardians of the regular-class students, all (or almost all) retained their desire to say everything right away and let their peers make mistakes. From that moment their vision changed: it was not much but it was proof that CLIS pupils had something to teach, to transmit to the 'grown-up CM1'.

In another school, CLIS students, thanks to the breeding of butterflies, became the positive pole of attraction of the whole school for a while. All the students from other classes came to their classrooms for 3 weeks and CLIS students were able to introduce and explain their work to the other students. This experience helped change the values within an institution as well as the vision of students without disability on CLIS students.

In another school, BP went systematically each year with his students, after a sequence, into a large number of regular classes to present what his students had done. They began by setting a small pencil questionnaire on the subject studied. For example, following the buoyancy sequence, they asked if a number of objects were flowing or floating. They realized that children in regular classes had the same conceptual difficulties as they had.

Finally, classes of an Institute worked with a regular class (which is rare) for three years, which again changed a changed many things and contributed to greater self-esteem on the part of children with disabilities and their increased esteem from children without disabilities.

What about the teachers?

Most primary school teachers, and specialized teachers, did not receive any university science training and preferred teaching basic courses, i.e. French and Mathematics in the classroom, with students in need of special education. Part of the reason for this choice is that students with disabilities have fewer hours of tuition than regular students because during school time such students need care. Even when, by chance, science was taught, before teachers engaged in the project *Handisciences,* knowledge was generally conveyed in a transmissive manner and students were rarely in a research situation. Following this it emerges that an inquiry-based science education, as advocated by *La main à la pâte*, was appreciated by the teachers involved in this project. They all wanted to continue doing science with their students using an investigative pedagogy. If we look at the responses to the questionnaire sent to teachers in 2017, we only received sixteen responses because some had retired, others had changed roles and others had changed schools. Of the eleven who, in 2017, were teaching in a CLIS (whereas in principle they should no longer exist), all of them continued doing science with their students. Of the sixteen teachers who responded, ten had no scientific training. Of these, eight say they have become more self-reliant both in classroom practice and in their search for resources and their preparation of sessions.

They further specify that this teaching has a positive impact on the development of oral language, on the acquisition of knowledge and reasoning. Eight point out that this teaching has an impact on the inclusion of students in a peer group. A consequence, not necessarily predictable a priori, is the fact that this approach has been transferred to other disciplines, as indicated by EP: "*The students developed a very active attitude of researcher. This research posture has been transferred to other disciplines. For example, during reading sessions, students identified that there were hypotheses to be made and validated*". EA: "*There was a transfer to maths. They were not in restraint, in fear of making errors*". CT: "*The method encourages students to be active, which has an impact in other disciplines*".

During the 2012 study day, one teacher stated that "*this way of working has developed a great deal of curiosity among students that has been found in other classroom activities. They took the stage of observation and also took the time to observe and reflect in Mathematics or French while often before, they had started a task too quickly*".

Moreover, it seems that the protocol proposed to teachers allowed a number teachers to train. The role of the interviews was important because it allowed not only human contacts to be created but also to anticipate the course of the sessions by reflecting together on questions that the teachers did not necessarily ask themselves. A small number would like to continue to be able to consult a scientist just in case. All greatly appreciated the study day and share their own professional development: "*I chose to get involved in this project because I wanted to deepen my reflection on science at school and wanted to meet other professionals to share our experiences. I'm doing more inquiry-based science education than ever before*" (MD). It appears that non-scientific trained teachers who participated in the project *Handisciences* for three years became autonomous. In addition, this project allowed teachers who were doing science to practice an investigative process, as indicated by SG: "*Before Handiciences, I did science, but did not necessarily use the process of investigation. Well, we learn every year, we must choose one or two areas and work hard ... Yes, it made me want to do things more seriously and intense ... I think now I could do it better without a support. I think I have also acquired better reflexes*".

Discussion

Our results concerning the investment of young disabled people are similar to those of Scruggs and Mastropieri (1994): the investigation process makes, according to teachers, pupils more active, more attentive and develops their curiosity. The appropriation of this approach also changes students' argumentative capacity, they become able to 'imagine in their head', that is to say, to ask questions, to make assumptions or simply to have ideas, to exchange with each other so as to be active in class. Investigation and manipulation also lead to a good memorization of knowledge discovered 'by doing', which is in line with the work of Nolet and Tindal (1993). All teachers unanimously note the benefits of such an approach to student learning, the acquisition of knowledge and skills as well as the contributions of group work and its positive repercussions on the classroom atmosphere when applied. Students learn to work together and develop social skills, such as listening, helping others, but also a better understanding of themselves and others.

Teachers say that this type of teaching makes students more curious, more active, more attentive and motivated. All note that their students have a lot of fun doing science. They also share their discoveries about unsuspected abilities and skills in their students, their ability to work in a group, whereas in these classes it was customary to consider each child individually because of differences in age and disability. Working in groups allows these children to acquire a certain autonomy, to listen to others, to respect them, which very often results in increased self-esteem. In the same way, some teachers point out that group work allowed the leaders to back down and the shy to assert themselves. Most teachers are pleasantly surprised to discover the ability of their students to reason and make connections with their daily lives. They also note that manipulation is a means that allows students not only to better understand but also enables them to remember what they are doing and memorize a number of notions. Of course, they agree that we should not be left with manipulation alone. In the same way, shy and insecure pupils have plenty of ideas when they move on to the realization phase of a technical object (see the electric carousel). Finally, a point often made in the reports of teachers, is that this type of teaching gives confidence to children. This is partly due, they say, to students' acquisition of what they call the 'trial-and-error approach'. Indeed, children are able to make suggestions, even hypotheses, and to verify them experimentally. The fact of making a suggestion that turns out to be wrong is no longer seen as a fault or a failure but as a stage in learning. Is it because the verdict is given by nature and not by an adult human being? However, there are children and even teachers who cannot stand bear to inscribe in the science notebook intermediate writings that may be incorrect. In general, it is important that children have understood that we learn by making mistakes and that it is not outrageous to leave traces of these errors (provided of course not to have these traces alone).

Regarding language, although the majority of these children struggle with reading and writing, they are able to make quality drawings or diagrams. Thus the passage through drawing allows some to overcome their blockages in relation to writing. However, the question of the modalities to be put in place for the acquisition of a specific vocabulary remains a permanent one for the majority of teachers.

One last remark: it emerges from all this work that the students who participated in the project, certainly have difficulties, for which it is essential to put in place adaptations, but that these difficulties are not located directly at the level of the science teaching, as this regular class teacher says (AD): "*Compared with regular classes, what I do in CE1 (K-2th grade) is quite close. I did not find any difficulties specific to the class of CLIS with respect to sciences, except reading and writing skills*". Similarly, a polytechnic student writes in his report: "*CLIS students retained as well* (as CE1 students) *what they had learned*". Thus, it appears that there are conceptual difficulties in science that are found in all students, handicapped or not. We saw some examples in the section 'Links with ordinary students', and others are detailed in the article of the review Grand N (Saltiel & Heitz, 2015). Thus, Elisabeth Plé[2] remarks that the difficulties in science are of the same nature for the regular-class pupils as for CLIS students, but magnified. Is this why the project teachers did not dwell on the difficulties faced by children according to their disability?

It seems to emerge that the approach advocated for this kind of science education is similar to an adapted pedagogy.

Conclusion and perspectives

All of these results indicate that practicing inquiry-based science education provides a great deal to students with special educational needs: pleasure, developed curiosity, knowledge, self-esteem, respect for others, mainly oral language development and enriching collective work.

While this may require some time for implementation, it is striking that a significant part of the difficulties (especially the conceptual difficulties) encountered by these students are of the same nature as those encountered by ordinary students. It is arguably possible to say that teaching students with disabilities allows to take a closer look at a

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number of difficulties that students may encounter, including ordinary ones, which leads to thinking about the appropriate answers to put in place. In a way, disability should not be seen as a problem, but rather as a resource. All these results deserve to be confirmed and would require additional work both in terms of conceptual difficulties that students may encounter and possible adaptations.

Another aspect of this work is teacher training. The project protocol was designed to help teachers not only practice science, but also to provide us with information about the nature of the difficulties faced by teachers and students, as well assessing the contribution of such training. This protocol, which provided teachers with pedagogical and human resources, took the form of a vocational training tool. Teachers who enrolled in the project quickly adopted the recommended approach. We realized that the system put in place allowed many teachers not only to be convinced that science education was as important as that of French and Mathematics but that they were now able to set up a sequence alone. The proposed sequences have been well accepted and have been helpful because, as some say, this has allowed them to think better about the adaptations to be expected. These sequences[3] were enriched, following the remarks and advice of the teachers collected during the interviews and study days. These were appreciated by all because they allowed for fruitful discussions between colleagues, the finding of unsuspected adaptations and interaction between educators and scientists. If there is one thing that must not be suppressed according to teachers, it is these study days (unanimous support on this). In addition, it seems that the protocol chosen for this project can inspire a certain type of teacher training. Should it still be experimented?

This brings up some questions about teachers in regular classes. Shouldn't non-specialized teachers work more often with specialized teachers? It would be interesting if they could sometimes be in an observation position in these classes for students with disabilities.

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3 Currently 19 sequences are available on the websites of INSHEA (http://handisciences.inshea.fr/spip.php?rubrique4) and La main à la pâte (http://www.fondation-lamap.org/ disability)

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