TEACHING MATHS WITH VISUAL SUPPORTS

An experiment at INJS in Paris (France)

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"given the demonstrated challenges in mathematics faced by deaf schoolchildren, it is surprising that no one has thought to, or perhaps been able to develop methods to utilize the visuospatial strengths of deaf students to their educational advantage"
Marschark & Spencer, 2010

Introduction

It is well known that deafness (here we speak about children with both pre-lingual and profound deafness) leads to atypical conditions of language acquisition, whether it is spoken or visual-gestural (Marschark & Hauser, 2012). It is therefore readily apparent that learning literacy (reading, writing) is an area where deaf children may face challenges. However, it is not the only one: difficulties may also be noticed in other academic learning areas where the linguistic dimension is less pregnant, such as mathematics.

International studies show that deaf schoolchildren tend to lag behind their hearing peers regarding mathematical achievement (for a review, see, among others: Kritzer, 2009; Pagliaro, 2010; Marschark & Hauser, 2012; in French: Roux, 2014). The Deaf students' mathematic achievement in school on average fails to compare with that of hearing students, from the young preschoolers until college students. The gap still remains despite both educational and technological advances (teaching with sign language, cochlear implant ...). Multiple factors have been put in light in order to explain this rather gloomy situation: lack of incidental learning, linguistic and cognitive factors involved in the practice of mathematics, etc. (Marschark & Hauser, 2012; Pagliaro, 2010; Roux, 2014).

Both researchers and teachers, puzzled by the difficulties which some young deaf people encounter in their appropriation of mathematics, raised the following issue: what kind of mediations should be

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used with deaf people when we intend to teach mathematics? Knowing that written language may be difficult to master for many deaf students – due to its strong constraints (sequentiality ...) - many authors suggest the use of nonverbal media. They recommend a pedagogy displaying visual and spatial presentations. For example, Nunes emphasizes the "need for visual supports" into the classroom (Nunes, 2004) and Kelly (2008) claims for specific training about creating visual-spatial representations in order to symbolize and map numerical relationships into problems.

Thus, the use of visual aids enhancing simultaneous processing of information is frequently recommended in most scientific literature in the field. However, this does not solve all problems. First, because we know that using diagrams and visual representations is not necessarily "natural" among deaf students (Blatto-Vallee & al., 2007). Second, because, as some authors have argued, we have to take into account the specific cognitive and metacognitive functioning of deaf children (Marschark & Hauser, 2011). Indeed, deaf students tend to have difficulties with sequential processes, and with the deployment of associative or relational processing strategies (Marschark & Spencer, 2010). Thus, deaf children's mathematic performances are probably negatively affected because of both partial representations they have in mind and tendencies to treat stimuli in isolation rather than integrating multiple characteristics of the problem situations they face or the conceptual knowledge they are learning.

The need to use facilitating visual mediations still remains, but we must also support and strengthen the capacity of deaf students to deal with complex problems as well as to improve their linking and multi-dimensional processing abilities (Marschark & Hauser, 2012).

Which tools for teaching maths to deaf students ?

The ACIM method (Cognitive Activity and Modeling Images[2]) is an approach displaying visual and graphic diagrammatic materials. It was primarily dedicated for people with special needs in language or learning. It was created by Henri Planchon (Planchon, 1989, 2013), a French mathematics teacher who worked as a professor at the Teachers Training University in Paris (IUFM[3]). The ACIM method involves training of both cognitive and metacognitive skills, working up mathematical knowledge by students, and development of abstraction. ACIM teaching material (Planchon & Roux, 2009, 2013) provide non-figurative visual and diagrammatic mediation. Students deal with complex problems and relational processing. By their complexity and systemic dimension, the ACIM diagrams are supposed to foster research, communication and active construction of knowledge by students. One of us (MOR) uses these practice sheets towards an audience of hearing students and is involved in developing this approach.

The ACIM method was presented at the National Institute for Young Deaf in Paris (INJS[4]) in 2010. A training session took place in 2011. So, several professionals from the Institute have benefited from an introduction to the practice of "systemic modeling" in various fields: teaching (general and technological), enhancing language abilities and real life educational support. Then, an experiment

2 ACIM: Activité Cognitive et Images Modélisées ; http://acim.ouvaton.org/
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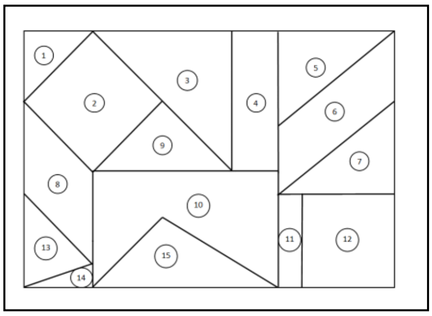
4 INJS: Institut National de Jeunes Sourds

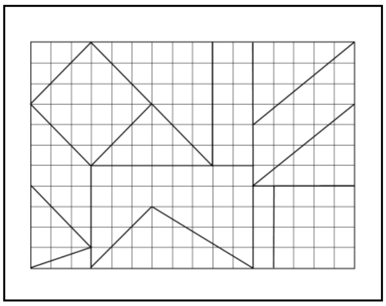
was set up at the INJS, as a part of the research missions assigned to this national institution. The aim was to estimate if such an approach could be useful for teaching mathematics to deaf students. Knowing the difficulties experienced by some young deaf people in their appropriation of learning, the question is: could such a visual, nonverbal, abstract and complex mediation be helpful?

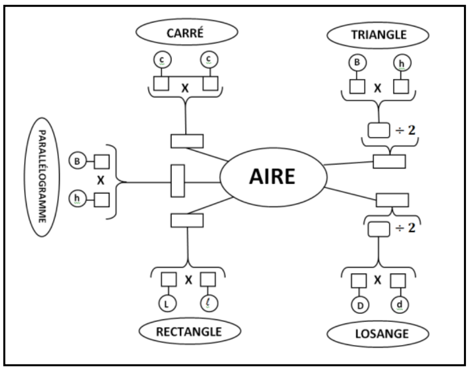
Preparatory study and qualitative evaluation

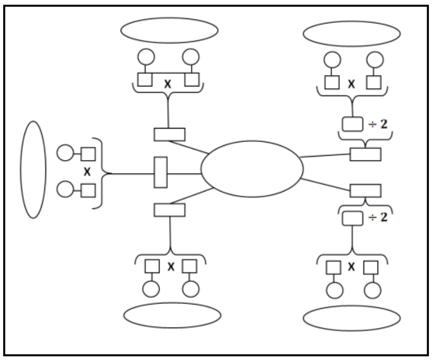
An initial study was conducted during the 2011-12 school year. One of us (EM), both a mathematics teacher at the INJS and as well as formed in ACIM approach, experimented during the school year several ACIM tools with a group of deaf students preparing a vocational exam (sewing or hairdressing options) within the institution. Topics included calculation of areas and proportionality. The choice of materials, their adaptation and the methods of operations were elaborated and discussed during several working meetings involving the two of us (EM & MOR) all over the whole school year.

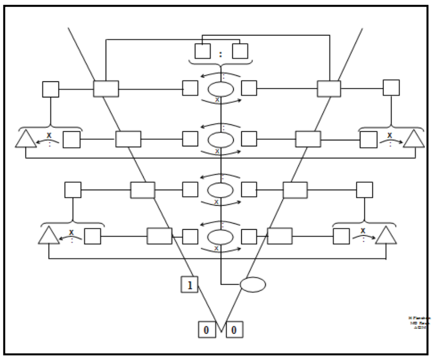
Examples of ACIM practice sheets that were used (original: H. Planchon, adaptations: E. Merlette & MO Roux):

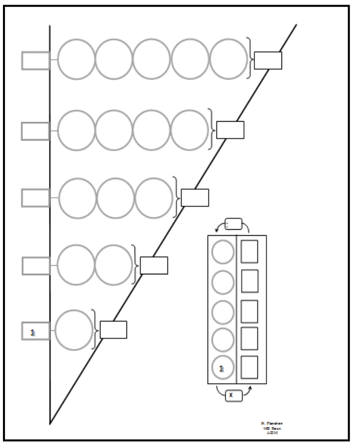












On this occasion, observations were collected, which can be summarized as follows:

- The reception of media by students:

Feed-backs received from students, as well as observations by the teacher himself (EM), suggest that despite their unusual appearance, the ACIM exercise sheets were pretty well accepted by the students - once they overcame the initial surprise caused by this novelty. Solicited to ask questions facing such complex nonverbal problems, students were puzzled. Therefore suggestions came from the teacher. He had to impulse the activity at the beginning.

- The work on the teaching material and the cognitive mobilization of the students:

The complexity of the diagrammatic media seems to have a motivating effect on the students. This was an opportunity for them to discuss, to debate and develop active research. Under these conditions, it is noteworthy that the group generally remained focused and active during most part of the math course, which is unusual in standard settings. These students showed themselves able to do some sort of research for a long time, even when they got not immediate responses or feed-back from the teacher.

- Learning:

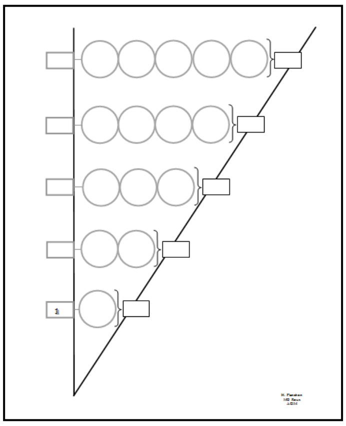
It seems that the visual material was quite appropriate for these young deaf students. Some of them said that visual algorithms and situations such as these gave them a better understanding of the formulas, and showed them how elements were linked (e.g. associating lengths and area or connecting a formula with its reciprocal). This last point is relevant because the majority of these students have had a school curriculum so far marked by significant challenges, especially in academic matters.

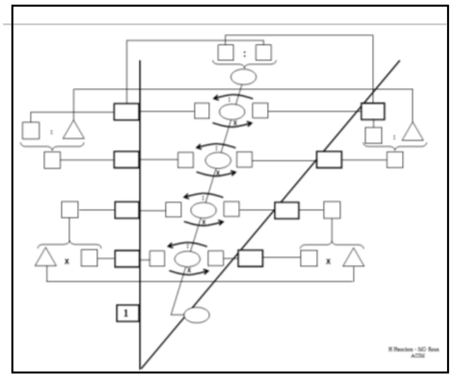
These initial observations from the field were both qualitative and partial at this stage of the experiment. They were interesting nevertheless. We then had to go further: are such visual and complex media likely to really improve the acquisition of math concepts by deaf students and to allow effectiveness through practical problems? Can such ACIM symbolic and schematic media facilitate knowledge's learning and memorizing?

Quantitative evaluation in experimental settings

A controlled experiment was conducted during the following school year (2012-13), with other students of the same grade level preparing a vocational exam. The aim was to evaluate the effectiveness of ACIM tools compared to a "classical" approach. We focused on the educational theme of proportionality. Proportionality is a concept with which such students were familiar, but which was far from being mastered for many of them. The material used (see pictures below), chosen among ACIM material, is designed to focus on the logic of the numerosities underlying proportion problems as a whole. It provides the opportunity for students to deal with problems involving the sense of multiplication or the sense of division, to seek an unknown variable in a proportion problem, and to explicitly visualize numerical relationships implemented in a proportional situation - including its various associated coefficients. The preparation and modes of operation were thought and discussed during several working meetings involving the two of us (EM & MOR) throughout the school year.

ACIM practice sheets that were used (original: H. Planchon, adaptations: E. Merlette & MO Roux):





Participants were students in the first year of their vocational curriculum, options hairstyling, carpentry, gardening, plumbing, locksmith-metalwork, sewing. They are young adults (ages between 16 and 22 years), boys and girls (53% and 47%), attending the National Institute for Young Deaf in Paris (INJS), with a hearing loss ranging from "severe" to "profound", only some of them using hearing aids. Their communication is usually mixed (French Sign Language[5], signed French, oral speech). They come from various social backgrounds. The overall educational level of the students, as estimated by their teachers, is ranging from "low" to "medium".

- Progress of the study:

Thanks to a pre-test (T1) we were able to split the students into two groups of equivalent level at the beginning: an experimental group (called "G-ACIM 1") and a control group ("G-T"). Then, the teaching of proportionality took place during several sessions in both groups, with an experienced specialized teacher (EM), in both Sign Language and spoken language. During the last course, an immediate post-test (T2) was given to both groups. At the very end, a retest (T3) took place about five months later, after the summer holidays.

T1, T2 and T3 are made of the same list of 10 short word problems (see Appendix). The subjects were not informed that they would be tested more than once, nor that it would be with the same items for the three assessments (T1, T2, T3). Some items involve implicit proportionality and can be solved using intuitive concepts or basic procedures (sense of multiplication or division): questions 1,2,8,9,10. Other items force the students to use expert procedures (calculating an unknown variable, fourth term, in a proportion problem): questions 3,4,5,6,7.

Both groups (G-ACIM 1 experimental group and G-T control group) were set up after T1 without the students being informed. They have a close supply size (n = 9 and n = 7) and reached an equivalent

5 LSF: Langue des Signes Française

level of initial performance (T1: 41% and 40% success rate). The number of participants here is rather low due to the organization of school classes in the institution. Both groups received the same amount of teaching hours about proportionality during the school year, by the same teacher (EM). The teaching provided to the experimental group was done with the two ACIM supports presented above, the control group was taught in a "traditional" way, the same way the professor had done in previous years (including drawing tables of proportionality, proportionality coefficient formula, "cross multiplying" methodology). Note that another group was taught with ACIM material (ACIM group-2, size n = 7), but its composition and level at T1 (74% of success in this case) did not allow us to compare it to a control group or to spread the students into the other two groups. We will refer to it marginally hereafter.

As a consequence of unforeseeable events in the institution and of the duration of the study (more than one school year), only part of the students which were involved during the early stages could be followed until the end. The results therefore do not involve large numbers:
- Control group (GT) : 7 students initially, 4 students passed the three tests
- Group ACIM-1 : 9 students initially, 5 students passed the three tests
- Group ACIM-2 : 7 Students initially, 4 students passed the three tests.

Finally, we got at least partial information for 7 "control" participants who received traditional instruction and for 16 "experimental" students who were taught with ACIM supports (9 participants ACIM-1 and 7 participants ACIM-2).

- Results:

They are summarized in the tables and graphs below:

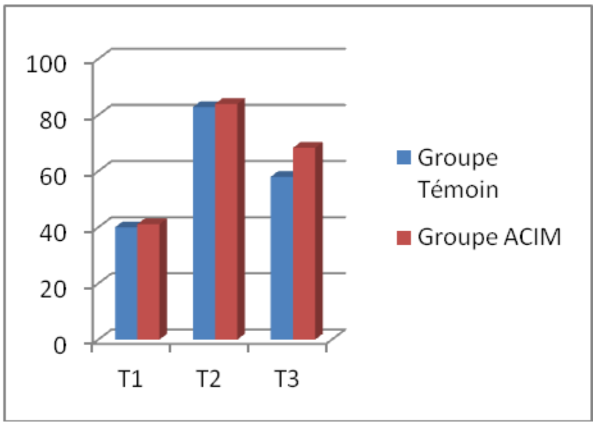
Table 1: percentage of successful items for Q1 to Q10 problems

	General		
	1st test : T1	**2nd test : T2**	**3rd test : T3**
	success	success	success
All (Control + ACIM 1 and 2)	**51,3 %** 7 + 9 + 7 = 23 students	**81,1 %** 7 + 5 + 6 = 18 students	**76,1 %** 5 + 6 + 7 = 18 students
Control Group (GT)	**40 % (28/70)** 7 students	**82,8 % (58/70)** 7 students	**58 % (29/50)** 5 students
« ACIM 1» Group	**41,1 % (37/90)** 9 students	**84 % (42/50)** 5 students	**68,3 % (41/60)** 6 students

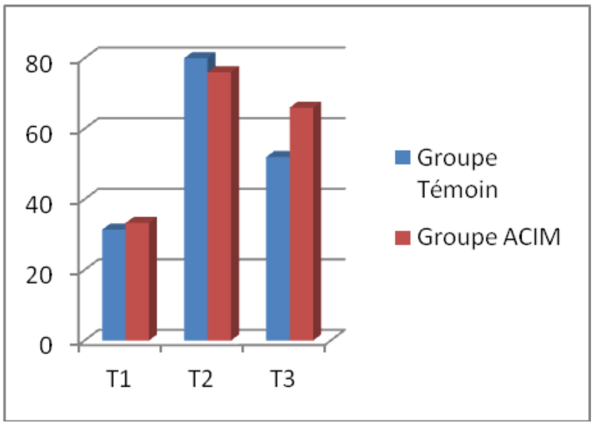
Table 2 : percentage of successful items for Q3 to Q7 problems

	Calculation of the 4^{th} term (Q3, 4, 5, 6 et 7)		
	1^{st} test : T1	**2^{nd} test : T2**	**3^{rd} test : T3**
	success	success	success
All (Control + ACIM 1 and 2)	**46,1 %** 7 + 9 + 7 = 23 students	**75,5 %** 7 + 5 + 6 = 18 students	**73,3 %** 5 + 6 + 7 = 18 students
Control Group (GT)	**31,4 % (11/35)** 7 students	**80 % (28/35)** 7 students	**52 % (13/25)** 5 students
« ACIM 1» Group	**33,3 % (15/45)** 9 students	**76 % (19/25)** 5 students	**66 % (20/30)** 6 students

General (Table 1): performance Q1 to Q10



4^{th} term (Table 2): performance compared Q3 to Q7



- <u>Analysis:</u>

Even if they are to be taken with caution, given the small number of participants, the results indicate the following comments:

- Results taking into account all available data, all groups:

- Table 1 shows that all groups increased their performance, from their initial level (T1), regardless of the teaching method and time of test (near or distant in time). Presumably, this would have been different with a group that did not receive any instruction on proportionality.

- The learning curve is not linear: there is some deterioration between the two post-tests (T2 and T3). This is a common observation regarding what it remains of a learning after a long time. However, despite the loss, T3 remains higher than T1 in all cases.

- All of these observations are still valid if we consider only the evaluation of the key items of proportionality at school, namely questions 3,4,5,6,7 (Table 2).

• Comparison of the experimental group with the control group

- Table 1 shows that both groups can actually be compared because of their identical initial level (GT and ACIM- 1, both about 40% success rate).

- Both groups greatly increase their performance as the instruction progresses and reach an equivalent level at T2 (GT : 82.8% ; ACIM-1 : 84%).

- Both groups maintain a higher success in the long term (T3) compared with pre-test, but the experimental group *loses less* than the control group (respectively 16% against 25%). 100% of GT lowers their performance, while 60% of ACIM-1&2 maintains or increases their performance. This suggests that, in the long run, knowledge with ACIM material would be better acquired and remembered in the mind of students, better than it is through traditional teaching.

• Others results:

- If we consider the results of all subjects for which all data are available (T1 and T2 and T3 completed), that is students who were continuously present over about 12 months, information becomes poor (n = 4, n = 5, n = 4 for GT, ACIM-1, ACIM-2 respectively). Despite this limitation, note that 3/5 of ACIM-1 and 4/4 of ACIM-2 doesn't decrease their performance between T2 and T3, while the 4/4 GT has a decreasing performance between the same two evaluations. The positive effect caused by ACIM approach on long-term memory would be confirmed.

- When we focus the analysis on the Q3 to Q7 results, pointing skills directly aimed by the teaching of proportionality in these grade levels, it appears that if T1 and T2 performance tends to be similar between the experimental and the control group, T3 ACIM-1 group gets 66% success rate while GT gets only 52% success. This would confirm that, speaking about expert procedures mobilized by typical proportionality problems, the ACIM materials could led to a better integration of knowledge.

Discussion and conclusion:

The teaching material that has been experienced in this study is visual, abstract (not figurative), nonverbal and systemic. It intends to enhance students' skills in active problem solving and relational representation of knowledge. We wondered whether these supplies could be a relevant mediation for teaching mathematics to deaf students.

The results are of two kinds:

- Qualitative ones: significant effects were observed in the first study (see above) and found similar in the second. That is: longer students' attention spans during class, a high involvement in research facing complex problems, good communication altogether within the group. We can hypothesize that the activity involved by a complex but nonverbal material contributed to support the research within this group of young deaf students and to enhance their metacognitive skills. In addition, the permanence of the media may have been able to support the development of knowledge through discussion and debate.
- Quantitative ones: the results indicate that the ACIM material which was tested did not demonstrate any discriminatory effect on learning itself, compared to more conventional methods. However, a difference occurs when we consider things in the long term. Learning with symbolic diagrams which put emphasis on visual-spatial representation should lead to more robust and better consolidated knowledge in the students' minds than traditional learning. This can be attributed to the systemic, generic and visual features inherent with ACIM materials. Students could have taken advantage of these characteristics in order to build inner visual images of mathematical concepts, to grasp relationships between notions, to memorize procedures which can be applied into contextualized situations. A better long-term success is important because it means, for these young adults in vocational education, an opportunity to use effectively the concept of proportionality into both functional and real world problems.

Of course, such results need to be consolidated through further research and subsequent studies - involving larger groups and addressing other learning themes or grades. Still remains strong hypothesis and hope that educational mediations such as those proposed by the ACIM method may contribute to put some light on the issue regarding how deaf children can learn better, and how to provide them with greater opportunities for academic success.

Appendix :

List of problems Q1 to Q10 (T1, T2, T3 tests):

- 1) A la boulangerie, le prix d'un croissant est de 1,20 €. Combien coûtent 3 croissants ?
    - *At the bakery, the cost of one croissant is € 1.20. How much are 3 croissants?*
- 2) On achète 5 kg de pommes pour 15 €. Combien coûte un kg de pommes ?
    - *I buy 5 kg of apples for 15 €. How much does one kg of apples cost?*
- 3) Une voiture consomme 6 litres d'essence pour 100 km. Combien consomme-t-elle pour 300 km ?
    - *A car consumes 6 liters of fuel per 100 km. How many liters does it consume for 300 km?*
- 4) A la superette, un pack de 3 bouteilles d'eau est vendu 1,50 €. Combien payera-t-on si on achète 4 bouteilles d'eau ?
    - *At the supermarket, a pack of 3 bottles of water is sold € 1.50. How much do we pay for 4 bottles of water?*
- 5) Pierre paie 2 pains au chocolat 2,80 €. Claire prend 3 pains au chocolat, combien paie-t-elle ?
    - *Peter pays € 2.80 for 2 chocolate croissants. Claire takes 3 chocolate croissants, how much will she pay?*
- 6) 25 litres d'essence valent 42,50 €. Le réservoir peut contenir 65 litres, combien coûte le plein d'essence ?
    - *25 liters of petrol are worth € 42.50. The tank holds 65 liters, how much for a full tank?*
- 7) Pour faire 3 km, un promeneur a marché pendant 36 minutes. En continuant à la même vitesse, combien de temps lui faudra-t-il pour parcourir 15 km ?
    - *For 3 km, a hiker walked for 36 minutes. Continuing at the same speed, how long will it take him to travel 15 km?*
- 8) Un paquet contient 8 biscuits. Combien y a-t-il de biscuits en tout si l'on a 5 paquets ?
    - *One pack contains 8 cookies. How many cookies are there in 5 packages?*
- 9) Le raisin est en promotion : 3,5 kg pour 5,95 €. Combien coûte un kg de raisin ?
    - *There is a discount on grapes : 3.5 kg for € 5.95. How much does one kg of grapes cost?*
- 10) La petite bouteille de lait contient 0,5 L. Combien y a-t-il de L en tout avec 6 bouteilles de lait ?
    - *The small bottle of milk contains 0.5 L. How many liters are there in 6 bottles of milk?*

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