DESIGNING A SIMULATOR IN BUILDING TRADES AND USING IT IN VOCATIONAL EDUCATION

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This paper deals with the design, the production and the uses of a simulator for the activity of marking out on building sites from reading a marked plan. The main design principle of this simulator lies in that it is not meant for reproducing accurately the real context of the activity but it should offer the possibility of posing problems of the work situation through a prior conceptual analysis of the professional activity.

What is a reading-marking out activity in a building work? Most of building tasks are based on reading plans for marking out on the building site. We call this kind of tasks, reading-marking out tasks. In a building site, setting out elements takes into account what will be set out later. For example, when a floor is to be laid down, the marking out of the floor must leave holes for water pipes and electric cables. Setting out a wall must plan location for windows and doors by marking out their contour. Such marking out is called “boxing out”. Generally speaking, a boxing out is a formwork placed in the middle of a structure before casting concrete, used to set aside an area in which additional equipment can be added at a later date. This task of reading information from a plan to mark out contours and boxing out on the building site is usual for workers in building trades.

Two types of controls can be distinguished in the marking out of boxing out:
- controls coming from reading information on the plan
- subsequent and effective controls at the moment of putting the additional elements (pragmatic controls),

the first type of controls being oriented towards the second type of controls.

The first type of controls is the focus of our attention. In absence of pragmatic control, only controls guided by knowledge about space and instruments can take place. The activity of setting out boxing out can allow researchers to observe conceptualisation and help them answer questions such as: what is the nature of knowledge involved in this activity? How is such knowledge organized and what relationship does it have with the artefacts available on the building site?

The observation of students of a vocational school gave evidence of a discrepancy between procedures of students and of professionals in this reading-marking out activity on building site from reading a plan. Two types of analysis were carried out in order to better know this discrepancy and to understand the reasons: an analysis of the geometry in action underlying the students’ activity in reading marking out tasks in workshop and an analysis of the transposition of the professional activity in vocational education was needed. The first analysis is presented in Bessot & Laborde (2005). The second analysis focused on the place and status of reading-marking out

activities in vocational education, in particular when preparing students to a certification of qualified workers for building trades (in French : Brevet d'Enseignement Professionnel). It was carried out and showed that the reading marking out situation that constitutes an indivisible entity in the professional practice is divided or almost absent from the vocational education institution (Metzler 2006). A simulator is for us a means of designing situations restoring the unity of reading marking out activity in the three teaching places of French vocational education in which knowledge about space is part of the learning aim: in the mathematics teaching (in particular geometry), in the teaching of construction, in the teaching of practice in workshop.

According to a key design choice, the simulator was meant as an *open-ended environment offering the possibility of constructing didactic situations* based on problems previously identified in the analysis of professional situations.

1. FONDAMENTAL PROBLEMS INVOLVED IN READING-MARKING OUT PROFESSIONAL SITUATIONS

Previous research on different types of space (Bessot & Vérillon 1993, Brousseau 1983, Berthelot & Salin 1992, Samurcay 1984) as well as the analysis of professional practices (Bessot & Laborde 2005) allowed us to identify three types of problems related to the invariants specific to reading-marking out situation. The two first types are related to mesospace, the third type to the instruments of the building site.

The first type of problems is the problem of locating the local space in which marking out takes place within the mesospace of the building site. Two types of space are involved: the local spaces in which marking out the lines is achieved, and the global space of moves that allows the worker to move from one local working space to another one.

Locating the local space requires coordinating three frames of reference (Samurçay ibid.):

- the frame of reference attached to the subject (egocentric reference frame)
- the frame of reference of the lines marked on the building site (allocentric reference frame) to construct from fixed existing objects of the mesospace that may also be lines already marked on the building site
- the frame of reference of the plan that is the dimension system.

The second problem related to mesospace deals with the coordination of local spaces (Brousseau *ibid.*) that may be distant from each other. This coordination is needed in the process of obtaining the expected global set of marked lines of mesospace.

The third problem is related to the use of instruments: transferring measures requires taking into account the features of the instruments.

2. CHOICES FOR SIMULATING MESOSPACE

In order to decouple the problem of local marking out from the one of moving and orienting were created two different windows: the first window allows the worker to have access to various local spaces but never to the entire space; the second one provides access to the visual field of the worker within the global space and his/her move in this global space. In the second window (global space) one can only move, in the first one, one can mark out by means of instruments and one can move without a general view (through the scrolling bars). Here are presented the features of these two windows.

Window simulating the local space for marking out

This window simulating the visual field of the worker with real dimensions 1,50 m by 1,10 m is the screen of the computer providing a representation of the real visual field on a scale of 1 to 5 (Fig. 3).

One can perform measurement and marking out with the simulated instruments (see below). This window is located within the global space for marking out which is not visually totally accessible. One can move in the global space from one local space to another one by using the scrolling bars of the window (Fig. 1) but with only a partial view at each moment making difficult the linking up of local spaces.

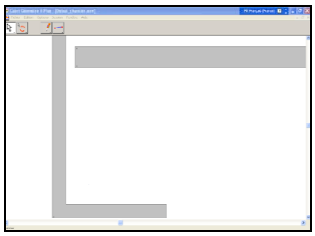


Fig. 1: Window simulating the marking out local space

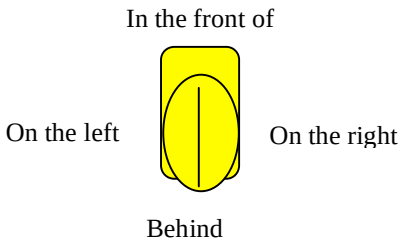
We wanted to simulate the change of viewpoint when the worker is moving away from or closer to the lines marked on the site. Zoom out (Zoom-) and zoom in (Zoom+) possibilities have been set up to simulate these moves, moving away and moving closer. Zoom facilities are limited in order to avoid a global view of the space for marking out. In addition, it is not possible to perform marking out when the zoom tool is active but it is possible to move the instruments. At any time, it is possible to come back to marking out by pressing the key “Zoom 0”. This zooming possibility makes easier an accurate reading of the marks of the measuring tape and the move from one marking out local space to another one at a small distance.

Window simulating the global space

In order to locate the current marking out local space within the whole space, it is possible at any time to have access to the simulation of the global space by pressing F9 key. The window global space is simulated by a squared vignette with a 7,5 cm long side representing a real squared space with a 5m long side (Fig. 3 et 4).

When opening the window, a yellow hard hat appears that represents the worker with its visual field represented by a rectangle. This rectangle is the image at scale of the screen (marking out local space). When opening the window, the yellow hard hat is always oriented vertically below the rectangle (Fig. 3, 4 et 7).

It was chosen to simulate the moves of the worker (yellow hard hat) and not its position (Fig. 6 et 7). Two moves are possible: shifts and rotations which are multiples of a quarter turn. Shifts are performed by directly moving the rectangle through the mouse. Rotations are egocentric and are performed by pressing one of the three buttons « > », « < », « »: to get the marking out local space on the right of the worker press button « > », on the left of the worker press button « < », behind the worker press button « ». When back to the local space (Fig. 6), the worker sees the lines oriented as resulting from the move performed in the global space window. In this way the decision of moving and the effect of the move on the visual field are decoupled. If from the marking out local space one comes back to the global view (F9 key), when opening the window, the yellow hard hat is always below the rectangle representing the local space (Fig. 7). Without a fixed frame of reference, the change of position cannot be inferred from the position of the yellow hard hat with respect to the fixed border of the screen.



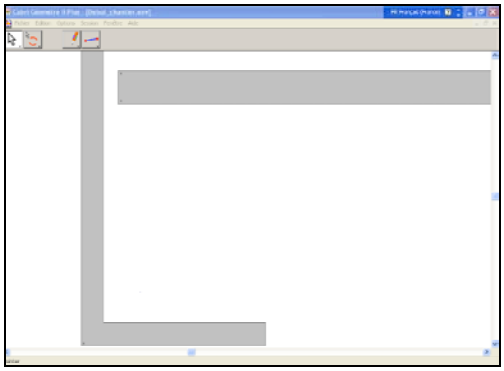


Fig. 2: Window «marking out local space»

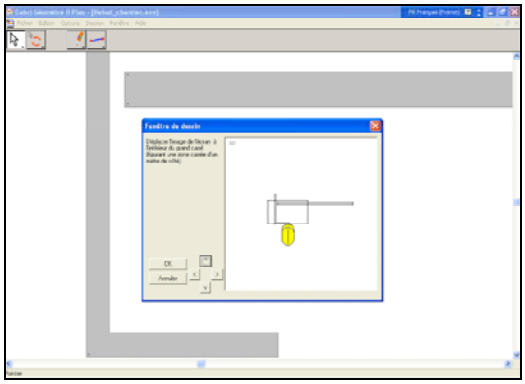


Fig. 3: Window global space in the screen (after pressing F9 key)

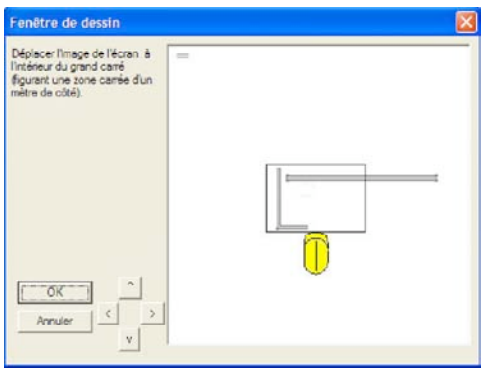


Fig. 4: Local space in the global space window

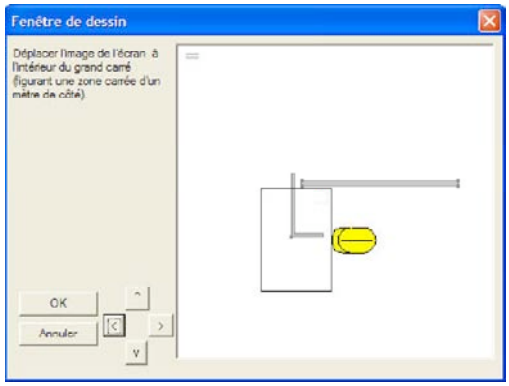


Fig. 5: After pressing button « < »

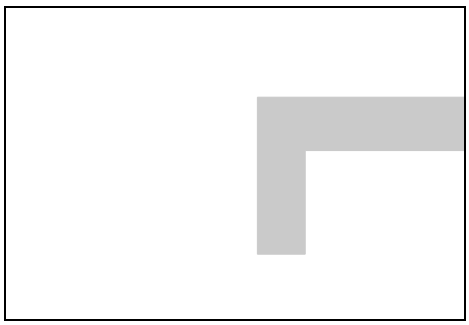


Fig. 6: After pressing « OK » back to local space

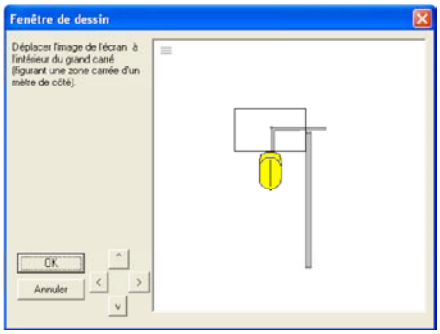


Fig. 7: After pressing « F9 » back to global space

3. CHOICES FOR SIMULATING OBJECTS

Choices for simulating the prefabrication table

The prefabrication table in which the slab is poured, is simulated by three rectangles with same width 0,05m joined in an U shape: the table is 4m long and 2,5m wide. When opening the simulator, the borders of the table may have various directions with respect the borders of the screen: parallel to the screen borders (see Fig. 8) or not (see Fig. 10). The U shape can be oriented in various directions (see Fig. 8 and 9).

Fig. 8: Prefabrication table parallel to the screen borders

Fig. 9: Prefabrication table parallel to the screen borders, in another orientation

Fig. 10: Prefabrication table non parallel to the screen borders

The table is not totally visible in the local space although as fixed object of this space, it can serve as frame of reference of the mesospace for locating lines in coordination with the plan. The table is only totally visible in the global space window (key F9).

Choices for simulating the use of instruments

The choices for simulating instruments deal with their aspect, their accessibility, their moves and their use. We decided that all instruments should look like real instruments. In particular their dimensions are proportional to real dimensions. The 2,5m long ruler and the 3m long tape even partly unwound stick out beyond the visual field (see Fig. 11 and 12).

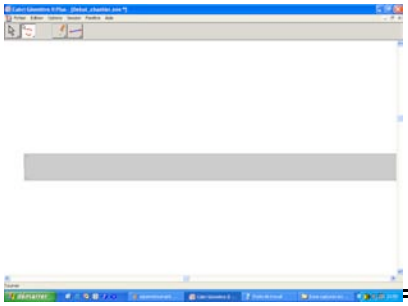


Fig. 11: The ruler cannot be totally seen

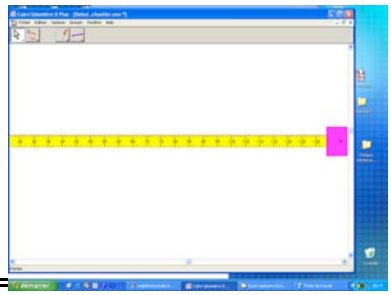


Fig. 12: Apart of the measuring tape

Marking out instruments, namely the pen and the blue line are permanently visible as icons at the top of the screen.

Instruments for measuring and transferring geometric properties read from the plan (setsquare, ruler and tape) are put at the beginning in three boxes labelled with their names, which are simulated by rectangles located in a corner of the global space accessible by moving in this space. Once an instrument is out by clicking on its box, the worker may have to move to find it again in his/her visual field (resorting to the global space window or to zoom) and to shift it in the screen (local space) to the adequate location in order to perform a marking out.

The materiality of the instruments was not preserved in that simulated instruments can overlap. However seeking to make the edge of an instrument coinciding with the prefabrication table or with the edge of another instrument partly replaces this materiality. However note that the simulated tape is also retractable as in reality in a pink squared case.

4. CONCLUSION ABOUT THE DESIGN OF THE SIMULATOR

One of the important contributions of simulators lies in the possibility of being freed of the constraints of reality, like the irreversibility of some actions or the time passage.

It is clear that the simulator transforms the relationships of the worker with space. But what is lost in fidelity can be gained in terms of problems and control. Indeed, in the use of the simulator, separating local and global spaces requires from the subject to make the decision of seeking information in the global space. To this end the subject leaves the local space in order to be and move in the global space, and then must come back in order to perform marking out. These conscious back and forth moves do not occur in reality. As a result of this separation, the subject is certainly faced with a coordination problem of frames of reference of the two spaces.

The additional action of back and forth moves between the two spaces is tedious, it transforms the reading marking out strategies and favours predictions to decrease the number of back and forth moves. But it gives rise to observations for the subject and

the educator and consequently can become an object of a reflexive work analysing strategies in real and simulated situations.

Another contribution of the simulator is the possibility of controlled variation offered to the educator. The same simulator can give rise to different uses in vocational education. The educator has the command of the type of use and of tasks given to the students. An example of a didactical situation is briefly presented below.

5. EXAMPLE OF A DIDACTICAL SITUATION MAKING USE OF THE SIMULATOR

The situation reported here raises the problem of continuing a marking out already done without transmitting to the worker information on what has been set out. This situation simulates a usual professional problem. Solving this problem requires that the worker identifies the local space within the global space by coordinating various frames of reference including the frame of reference of the plan.

Instructions

The plan of slab 1 with three boxings out is given (Fig.13) to the students.

1) Open the file “slab 1”
2) As visible, the contour of slab 1 and one boxing out have already been marked.
3) Mark out the two other boxings out of slab 1.

Here below is given the plan of slab 1 provided to the students as well as the windows local space and global space.

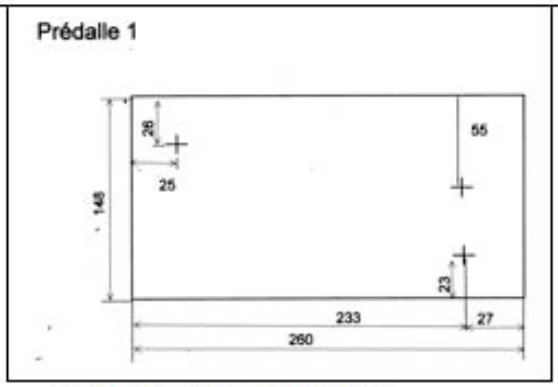


Fig. 13: Plan of slab 1

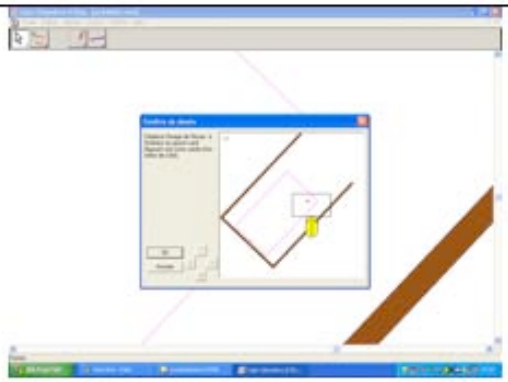


Fig. 14: The two windows

The plan is oriented by the orientation of the writing (from left to right and from top to bottom) and consequently imposes a position for reading. It is represented in this position on Figure 13. When opening the file “slab 1”, part of the prefabrication table, part of the lines and the boxing out R(25, 26) are visible in the local space (Fig.15).

In figure 14, it is visible that the slab is rotated through 180° with respect to the frame of reference of the plan.

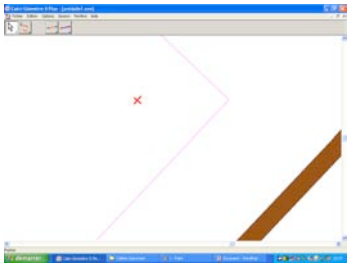


Fig.15: At the opening of file slab 1

A priori analysis of the situation

In the marking out activity, the worker's aim is to reproduce in the mesospace the image of the drawing of the fabrication plan. The continuation of the marking out requires interpreting the boxing out already marked in mesospace as the image of a boxing out of the plan.

Two cases are possible:

- Either the plan and its (*unfinished*) image in the working local space have a similar orientation and the boxing out is erroneously considered as R(27,23)
- Or measures are taken in order to identify the already drawn boxing out with a boxing out of the plan.

The choice of the dimensions of boxings out in slab 1 is deliberate. The distances to the border of the two boxings out R(25 ; 26) and R(27 ; 23) are visually close, favouring thus the mistake of the first case in absence of the professional gesture of taking information on what has already set out.

Incorrect interpretation of the already marked boxing out without measuring : R(27 ; 23)

Two other boxings out must be marked. Here is only considered the case of boxing out R(27 ; 55) as the only one likely to lead to feedback. Two procedures for marking out R(27 ; 55) are possible:

- Either through an alignment with R(27 ; 23) by resorting to the only measure 55 : *no feedback*.
- Or by resorting to two measures 27 and 55 without making use of the alignment. Once the marking out is done, *the absence of alignment of the two marked boxings out provides feedback that leads to reject the interpretation of the existing boxing out a*s R(27 ; 23). This leads to the second case which is analyzed below.

Correct interpretation of the already marked boxing out through checking by measuring: R(25 ; 26)

The coordination between the plan and its unfinished image can be achieved in two ways.

- *Real or mental half turn of the plan of slab 1*

The plan is rotated through 180 ° effectively or in thought to superimpose the image on the screen with the rotated plan: the marking out is performed with a prefabrication table in the position “open on the right, closed on the left”.

- *Move in the mesospace through resorting to the global space window*.

To keep the prefabrication plan in its privileged position and make it coinciding with its image on the screen, it is possible to use F9 key to get access to the global space in order to simulate a half turn in this space: the table is then in the position “open on the left, closed on the right”. When back in the local space, the boxing out already marked is the image of R(25 ; 26). Boxings out can be marked in the same position as they are on the plan.

The situation is aimed to provide multiple opportunities in which checking measures of marked objects in mesospace (prefabrication table, lines) lead to an economy in marking out. Checking is a critical gesture of building trade as claimed by the educators in vocational education.

A posteriori analysis of the situation

As displayed in table 1, only 3 pairs out of 5 resort to measuring on the marking out, in order to identify the boxing out.

Interpreting the already marked boxing out	without measuring	with measuring	
	R(27,23) *Pairs 1 and 2*	R(20,21) then R(27,23) *Pair 6*	R(25,26) *Pairs 4 and 5*

Table 1: Checking procedures of already marked boxing out

Let us analyze the checking procedures of the three pairs 4, 5 and 6.

Pair 4 made two checks by measuring the dimensions of the slab and the dimension of the already marked boxing out (26 cm) which is sufficient for identifying the boxing out.

Pair 5 checked only one measure (26 cm) and did a half turn of the plan to make the screen matching the plan.

Pair 6 drew surprising conclusions: the already marked boxing out is first considered as not in the plan, then as the erroneous boxing out R (27, 23). Verbal interactions among students V and N of this pair allow us to understand those successive conclusions. As pairs 1 and 2, V immediately identifies the already marked boxing out as R(27,23). But N insists on measuring. Then he measures one of the dimensions of the boxing out and obtains 20 cm as a result of a wrong use of the measuring tape: the distance is measured by making coinciding the centre of the boxing out with the border of the case of the measuring tape (with width 5 cm in real size). He then measures the second dimension in the same way and obtains 21cm. Surprised not to find any boxing out of the plan, he resumes each measuring twice or three times.

V: it fits nothing. It means that it is already marked, then we must mark out the three others. We make one more, that's it.

N doubts that there can exist 4 boxings out and asks questions about the use of the measuring tape to observer O. He admits that he never used a measuring tape!

N: the end of the tape, is it at the black mark (corresponding to the clip of the real tape) or at the other end?

O: it is at the black mark as on a real tape… do you know, don't you?

N: No, I don't know, I never used a tape.

V: Didn't you?

The doubt about correct using of the tape as well as the cost of its use in the simulator lead them to give up checking the correspondence between measures and dimensions on the plan. They come back to the first opinion of V, i.e. identifying the already marked boxing out as R(27,23).

The simulator made possible to face the students with the usual professional problem of continuing a marking out, which is a fundamental issue of the professional activity, as claimed by the teachers. The simulator revealed that even at the end of the vocational training, almost half the students do not resort to checking and among those who checked, the use of instruments may cause difficulties. This checking professional gesture is not available to all students at the end of the school year.

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