WIMS: AN INTERACTIVE EXERCISE SOFTWARE
20 YEARS OLD AND STILL AT THE TOP

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WIMS (Web Interactive Multipurpose Server) is a collaborative, open source e-learning platform hosting online interactive exercises in many different fields such as mathematics, chemistry, physics, biology, French and English among others. It is widely used in France mainly in mathematics from secondary school and up to the first university years. Using it in a proper way can bring advantage both to students and teachers.

Keywords: e-learning platform, grading, motivation, pedagogical alignment, community of practice.

INTRODUCTION

WIMS (Web Interactive Multipurpose Server) is a collaborative, open source e-learning platform, under the GNU (general public license), hosting online interactive exercises in many different fields such as mathematics, chemistry, physics, biology, French and English among others. It is used mostly in France [1] and mostly in mathematics in high school or during the first years of higher education [2]. It provides real learning advantages for students and for teachers. In this paper we will first present a quick history of its first development and describe the communities of developers and users. In a second part we present the way the software is built and how it interacts with other softwares. Then we present the advantages using such an exercise software can provide to students in terms of learning, skills development in a specific subject area but also in cognitive skills development. We will then discuss some observation we have obtained during our implementation of WIMS in UPEM. In the last part we give some hints to start with WIMS and conclude.

A BRIEF HISTORY OF WIMS AND THE COMMUNITY AROUND IT

WIMS has been first created by Xiao Gang (1951-2014) [3]. The initial version is released in 1997. Professor XIAO Gang was a brilliant mind, born in China, professor of mathematics at the University of Nice (France), one of the best world specialists of algebraic surfaces. Ten years after the first release, the association WIMS EDU is founded, and Xiao Gang leaves the software in the hands a small community of developers. The development is then taken over, mainly by Bernadette Perrin-Rioux in a mastery way. The association WIMS EDU [4], whose main goal is to support the diffusion of WIMS, organizes, among other things, once every two year, a colloquium attended by more than a hundred persons.

WIMS was created at about the same time as Google (registered on September 15, 1997) and long before Wikipedia (created in January 2001) or Moodle (first release in 2002). Comparing WIMS to these giants may seem to lower it's impact. But the mere fact that it continues to exists after 20 years, is still growing, has a wide community of users both teachers and students, an important community of exercise developers, and a very active and effective community maintaining and developing the software itself, is significant and remarkable.

It appears, from different statics and surveys, that classes in WIMS are almost only created by teachers, mostly french, proficient and very involved in teaching. We have no evidence showing students using WIMS by themselves, without belonging to a WIMS class created by a teacher. Whence, in terms of teaching theory, WIMS appears to be class depended with the teacher as a key-stone.

WHAT IS WIMS

In this part we will first explain the real specificity of WIMS: the WIMS exercise, and then explain the whole environment it provides to student, to teacher, and to exercise developer.

WIMS's interactive random exercise

The main specificity of WIMS is it interactive exercises. Most LMS develop interactive exercises such us MCQs, matching, drag-and-drop exercises. WIMS can do much more. It provides a framework and a specific language that allows to use very powerful softwares as MuPAD, PARI/GP, Octave, Gnuplot, POV-ray, Coq proof assistant, GeoGebra among others. Thus formal calculus, drawing figures can be made quiet simply. And truly new and original exercises can be proposed to students.

The most original feature of the WIMS exercise is its random feature. To make it simple, let us consider a very simple example and look what is necessary in order to check whether a student can add small numbers. A naive way to achieve it is to program a question *2+2= Answer Field*. The student's answer is stored in the variable *StudentAnswer*. The *TrueAnswer*, here "*4*", is compared to the *StudentAnswer*. If these two variables are equal the student receives the notice of success. If the variables are different, *TrueAnswer* can be displayed and more feed-back can be programed.

In a WIMS exercise one doesn't program the question *2+2* but *a+b* where *a* and *b* will be variables randomly chosen by WIMS between values determined by the programmer, for instance integers between 1 and 10. When the student calls a cession of a WIMS exercise the software presents a random draw of *a*, *b*. Thus in several lines of programming one can obtain an exercise that will have a great and maybe almost infinite versions. For examples of WIMS exercises we advise the reader to explore a WIMS server [5].

WIMS allows a to have a direct access to mistake. Once the answer's given in one clic WIMS displays if the answer's right or not. In most cases the right answer can be given. However, when there is more than one solution for instance, it can be more tricky to program. Consider the following WIMS exercise: *Let A be a subset of the real numbers defined as follows: A= .... – Is A bounded (yes or no) if yes give an upper-bound of A*. Here, the programer decides to chose randomly the set *A* between union or intersections of intervals, set of the values taken by types of sequences, values taken by a quiet simple function. The programmer may calculate for each type of examples the supremum *s* of the set *A*, and test if *s* is less and equal than the answer *m*. When the student is wrong, his answer *m* is strictly smaller than the supremum *s*, programming the feed-back of the exercise in order to get an element *a* in *A* which realizes *a>m* can be a much greater brainteaser. Of course the feed-back can just propose a content where a similar example is solved.

WIMS as an LMS

WIMS belongs to the class of LMS (Learning Management System). Anyone, with web access and an e-mail address, can create a virtual class and become a teacher on any WIMS server around the world in less than 2 minutes. Then the new teacher has two tasks: first build the resources of her class, and then enroll the students. Building the resources consists mostly in choosing or creating

and organizing the exercises in sheets of exercises. There are short ways for doing it. For instance if a so called *Classe ouverte* corresponds to the teachers aim, she can in several clicks copy it and have it privatize for her own students.

Of course, it can be customized, exercises can be changed, added, taken away. One can also (it takes two minutes) restore a class built previously and backed-up. A research engine can also propose full exercise sheets corresponding to the key-word and to the level, and thus import parts of the class structure in a fast way. The research engine can also help you to select exercises one by one. An important task, which has many pedagogical implications, is the choice of evaluation and rating. Several parameters have to be set. The *severity* (if one mistake is heavily paid or not), the *rating scale*, *i.e.* the way the grade obtained in several repetitions of an exercise will be taken into account (will the final grade be an average of all trials, of the last *n* trials, of the best *n* trials, the worst of the best *n* trials…). Let us underline that the choices made by the teacher can influence motivation of the students, sustainability of the training. One has to be aware that sometimes good grades does not mean good work, if for instance a gambling strategy allows to obtain the maximal grade in a short amount of time. An interesting modality of parametrizing exercises is to make *strings*. A string is a pool of exercises made of several steps, each step can be one item of the exercise or an item of a different exercise. For instance the second step of the string adds a new kind of difficulty to the exercise proposed in the first step. The grade is given at the end of the string. Counting on gambling to fulfill a string of exercise is no longer a time saving option. And taking the time for deep understanding becomes a time gaining strategy. The teacher can also define the *weight of an exercise* in its exercise sheet, the *weight of exercise sheets* in the global average. The task of choosing the exercises and the parametrization of a class is the occasion of a didactical reflection. Sometimes it is time consuming. After all, composing a classical exercise sheet can also be long. Of course, if there is no resources corresponding to your curriculum in WIMS, you always have the choice of developing them. And this involves even more time.

The second task is to enroll the students. Several modalities are possible. One of them consists simply to provide them with the address of the server and the name and the code of the class (the teacher chooses this code while creating the class). They can then enroll by creating their private user name and password. The teacher may also registers the class students, creating user names and passwords. It is also possible to use directly a CAS identification.

WIMS' Analytics

The student, when she enters her class sees the sheets (you can have a very precise overview by entering in a *classe ouverte*) organized by chapters. At the bottom of the sheets one sees a tool-bar composed of little squares, each corresponding to an exercise (or a string of exercises) that will be green once she has succeeded. Thus in the glimpse of an eye, she can see where she stands, what she has achieved, what has to be done. By clicking on one sheet she has access to the list of exercises composing the sheet. A last click and she is confronted to the exercise and thats where the work begins. Of course at any moment she can consult *mes notes* that is *my grades*.

The teacher, can also see in his class the results of each students first by global average, by average on each sheet, or detailed in one sheet exercise by exercise. Other statistics of the class can be found. One of the very meaningful is the *indice de difficulté d'un exercice*. It indicates the average number of times necessary to get the exercise done. Clearly if this indicator is between 1 and 2, the exercise isn't difficult. Experience shows that when this indicator is above 3, the teacher should consider explaining the solution to the exercise to the class.

Let us mention that the teacher can also set groups by defining "variables techniques", say group A, B, C. A group can be given specific exercises and the day set to open or close a sheet can be specified depending on groups. Of course, analytics can also be sorted by these variables.

An LMS which favours sharing

We want to underline two strong specificities of WIMS which make this server so unique. First, the very rich typology of exercises, enabled by the use of powerful software. It allows, once one has mastered the programming language, to create in several lines a very large set of versions of an exercise. Second, it is one of the rare existing LMS which allows and encourages sharing exercises. Indeed everyone who creates his exercise is then invited to publish them. After some review on the code and of the content, the exercise enters in the common base and is published under a free license. Then anyone will be able not only to use it but also can register the code of the exercise in his own class and change or modify it. This specificity is very rare, and users of WIMS are very attached to it. Of course the procedure of edition could still be more fluid and the searching engine improved. It is an important demand of the community of users and work is being currently done.

The economical model

WIMS is under GNU license. It is thus a free and open-source software. The resources published in WIMS are also published under a free license. WIMS during his 20 years long life, has not receive directly any founding from public authorities. The software developers are volunteers. So are, in a major part, the exercises developers. Though one can nevertheless consider that there is some public funding when a university attributes a server to WIMS and maintains it, or if some institution pays out the creation of exercises.

There are some wishes to evolve on this model, to be able to benefit from a IT provider to develop some aspects of the software. It appears though [14] that, for developers and users as well, a crucial value of WIMS relies on its sharing potentiality. The free and open source model relying on benevolent contributors (as wikipedia) is certainly the best model to support this value.

WHAT ADVANTAGES WIMS PROVIDES TO STUDENTS – OUR THEORY

Learning an unknown area of knowledge can be hard time. To grasp it, one relies on previous knowledge and skills, and on indications from the teacher, not always well understood. The faster one has to handle and manipulate the new material, the better. Yet first time can be hard. F. Garnier shows an experiment where more than a hundred persons were asked to open, for the first time of their life, a pressure cooker, with the help of a drawn instruction. The video shows a young woman fighting for opening it and achieving it in 104 seconds [6] . And then she does it again in 2 seconds, as anyone. WIMS allows to take the necessary time to achieve a task. Then, in the way to expertise, rehearsal is needed. Again WIMS meets this demand.

Let us underline that the human brain is much more analogical than deductive by nature. And the mathematical activity is clearly an activity which requires both ways of thinking, deductive of course, but also analogical during the creative steps. For an analogy to be made, one has first to experiment a number of different cases.

The necessity of multiplying examples of different type of representation in order to allow students to form a good representation of a problem is very well explained in Cordier & Cordier. It appears clearly that students only exposed to the use of Thales theorem when the parallels are from the same side of the intersection of the two scant lines, have a lesser possibility to understand the whole generality of Thales theorem than those exposed to a greater generality of cases. WIMS clearly

meets this purpose. It's random features pushes the creator of an exercise to imagine a variety of examples and to encode them.

Let us also recall the celebrated lack of differentiation between the concepts of length and quantity for small children. Piaget's experience consists in showing two sets of 5 balls on a line, but the second set of balls are closer to each over than in the first set. Children are asked which of the sets has more balls. Up to six years, children answer that there are more balls on the line where the balls take more place. It appears that small children have some difficulty in distinguishing between length and number. Mixing up two concepts does not require to be under six, and a good discrimination comes not only with age but also with the occasion of seeing multiple situations and understanding their common features and differences. Again, as WIMS allows to offer the students an occasion to work and a wild diversity of cases, it can be used to train their discrimination skills.

If the deductive way of proving is certainly the most used in school especially in teaching mathematics, let us underline that the analogical thinking seems strikingly effective and deeply wired in human brains. To learn what is a cat or a dog no needs to explain. Present several items is enough. And then the animals will be recognized with no cognitive expensive. Achieve this type of quick recognition can be an important skill in learning. Again WIMS allows to enforce such type of learning thanks to the diversity of exercises it can generate.

Another celebrated experiment by Kahneman is the *Linda experiment:*

> Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations. – Which is more probable? (A) Linda is a bank teller. (B) Linda is a bank teller and is active in the feminist movement.

It appears that 89% of the persons asked answer (B), which is in fact false because (B) is clearly a subset of (A) and therefore has a smaller probability. This example illustrates the existence of two modes of thinking, fast and slow. The fast way of thinking, or system 1 – which works by analogy and is closer to feelings – jumps to the conclusion that Linda has to be at least active in the feminist movement and cannot be only a bank teller and thus chooses (B). When the emotional context is very vivid, the mathematical way of thinking, which is slower, has almost no chance to take over. And indeed, even when the persons interviewed are specialists, the number of wrong answers is surprisingly high. Olivier Houdé argues that the only way to get out of this dilemma is to work on what he calls system 3. In order to be able to let system 2 to work, one has first to inhibit the fast system 1. This can only be done by using an emotional key. This key is the shame of having been mistaken a first time. Thus doing mistakes is a fundamental step in constructing knowledge. The uncomfortable moment when a mistake happens generates thus the possibility of updating the thinking process which has caused this mistake. Moreover making this mistakes appears to be a necessary step. And one has to suffer its bitterness to be able avoiding it later. Better to experience it while training on WIMS.

If training is very central to learn, the influence of grading should not to be neglected in order to motivate students and push them to repeat. Experience shows that repetition is not always the clue to successful learning. Indeed if you choose for rating scale "*the best of trials*" or "*the mean of the three best trials*" the result is an increasing function of the answers' number. Letting chance decide, a wining strategy requiring no endeavor, might be chosen by some students. With no profit in learning. On the other side, choosing a rating scale involving *quality* (Q is calculated as a mean of the grade of all trials with a decreasing influence of the first ones), fosters another deviant behavior.

Some students are ready to pass hours on an exercise to improve the quality indicator repeating over and over an exercise they have understood. With no profit in learning again. At UPEM we are found of *strings* with very *high severity* index and we take the best of the trials. To obtain full grade on a string of four or five items with a high severity requires some mastership.

Research shows that memory, in particular *working memory*, is one of the best predicator of success in studies. And research shows that it can be trained by proper exercise. The main impact of mental arithmetics, to which generations of children where submitted together with the learning of dead languages, was perhaps the development of working memory. Thankfully, it can be trained at all ages and has similar characteristics as physical training: it is particularly efficient if it fits to the level of the training person. WIMS allows, to some extent, to individualize training and to enforce working memory. WIMS exercises, proposed with proper grading, can also enforce *attention*: students are particularly cautious at the last item of a string of four questions, and analyze the question with mindful attention. The diversity of types of questions which allow to ask questions of different types enforce *processing*. Sequencing as well can be strengthen. A possible scenario is to propose an exercise whose solution needs *sequencing*. A first the student is asked directly for the final result. If she does not succeed, the exercise is proposed in a sequenced form, step by step. Once it has been done with success the question is asked again directly.

EXPERIMENTING WIMS AT UPE: AN IDEA PROJECT

The community of Universities Paris Est (UPE) has won a call for project called (IDEA) in the context of « initiative d'Excellence en Formations Innovantes » (IDEFI) and of the Programme Investissements d'Avenir (PIA) financed by the Research National Agency (ANR). The project allowed working groups to get support in order to set and experiment pedagogical disposals. It appeared to be an opportunity to develop and test the use of WIMS during the first year of mathematics at university. This project started in November 2014. There are four mathematical courses, each one corresponding to 6 UCTS and to 2 hours of lecture and 3 hours of tutorials. The principle aim of the project was to build pathways of exercises corresponding to each of the learning module.

There exists huge numbers of exercises in the common base of WIMS corresponding to the first year after bachelor degree and we could rely on this resources. In addition hundreds of exercises have been developed, especially basic ones. For each chapter of the courses two sheets of exercises have been created, a basic and a standard one. Each sheet is composed of 8 to 15 strings of exercises. Within the basic sheet, exercises give the occasion to manipulate directly elementary notions of chapter. The standard sheet aims to propose exercises which correspond to the recourse's level. With one big difference: WIMS does not train writing a proof. Yet with a part of the training made on WIMS, more time can be spent in the classroom to practice this competency.

We choose an evaluation in WIMS with exercises's strings, high severity, and the best of the string success for grade. The sheets are opened for two weeks. After closure, students can continue to practice, but the grade is frozen. We use WIMS as a formative assessment. Its grade counts for a part of the continuous assessment. The final grade is given by the maximum between the exam from one hand and the average between the continuous assessment and the exam from the second hand. The work on WIMS has to be done outside of the classroom. If asked, teachers answer questions and use video projector to address some examples. A tutorship system is organized. First compulsory during the two pre-entry weeks, a daily permanence is then opened at noon along the whole academic year. The mentorship is provided by the top students of the previous years.

It appears from WIMS statistics that students work on WIMS for 2 to 3 hours on average. The amount of time does not depend of the student's level. Good student finish all with the maximum grade whereas average students may have trouble to succeed the full standard sheet.

Anonymous inquiry has been proposed. In the first semester of year 2016-2017 we obtained 82 answers on a promotion of 250 students. The inquiry dealt not only on WIMS but on all the aspects of the course. Concerning WIMS, it turns out that it has convinced users. More specifically 84,2% answered that WIMS' goals have been reached. A large majority thinks that the evaluation was clear and just. There was some complains about the time during which the sheets were opened. Indeed at the end the semester this information hasn't been provided clearly enough due to some overflow of the teaching staff. But a large majority (70,7%) declared to be satisfied by WIMS. Concerning learning methods, we are faced with students lacking of method. This is made clear by the way they engage in learning: only 7% answer that they open the course notes or the lecture notes shortly after the course, about 54% open it while preparing to an evaluation, and 49% read there notes while working on WIMS. This enables us to think that WIMS may be a tool that fosters working on the course itself. 78% used a scrap paper while doing WIMS exercises. Hence WIMS invites students to mobilize appropriate tools to build their thinking paths and answers. This remark has to be set against the fact that only 36,6% declare paying sustained attention to the reading of the statement of the exercises. Half of the students did not appreciate the feedback given by WIMS. More investigation has to be made to understand why.

According to 83,3% of students, WIMS helped developing competencies in mathematics. Some give testimony from which it seems to appear that it is through WIMS that they understood the principal course concepts and have begun to construct their mathematical thinking. According to 43% of students, WIMS has also helped to develop meta-competencies. This inquiry seems to establish first that WIMS was a truly effective tool in order to structure time during which students had the occasion to mobilize the resources of the course. Second WIMS invites the students to be rigorous in calculous or in reasoning, this fact has been often underlined. Third the exercise paths could still be optimized as students stipulate that sometimes the exercises are repetitive and the time required to achieve the exercise sheet is sometimes too long.

SOME HINTS TO START

Let us emphasize that organizing complete pathways of exercises is time consuming. It usually takes 3 years of work unless one can find resources that correspond to the wishes. If nothing corresponds, you've got to start programing.

Of course the main task is to align the pedagogical objectives and work on the coherence between lectures, classical exercises, class practice, WIMS exercises and exam. With striking efficiency, as shown in Berland 2017.

Here some pragmatic points. First, students have to be paid for their work: the grade obtained in WIMS has to be taken in account. Second, it is important to propose easy exercises which allow to work on basic notion of the course. Third, the sheets have to be apparently not to long and having one easier sheet to begin a chapter is a plus.

To preserve engagement of students, and to foster the efficiency of training on WIMS, teacher should follow students' work, speak of WIMS in class, and address some examples, especially when an exercise has a difficulty index greater than 3.

To preserve teacher's engagement, having contacts with WIMS EDU in order to enter a community of practice is a true help. Yet, WIMS gains to be part of the school or university project, to appear in the institutional brochure. Moreover, teacher promoting its use, by developing exercises for instance, should receive some kind of compensation.

To conclude, we underline again that WIMS is 20 years old. In 1997 it was really a visionary tool. And even if some parts would gain to be updated, it still is at the top. One of the greatest strength is its community and its free and open model. This allows to use and share exercises and possibly whole classes of exercises. We underline that there is something in the values shared that fosters a great engagement from the volunteers developing exercises and the software itself. Is the heroical time where the entire development is sustained by volunteers finishing? Will the model be updated in order to be able to sustain the payment of providers, needed to develop the software? Its future is not yet written. But whatever happens, these fundamental values, that foster engagement, should be carefully preserved. As for the pedagogical advantages of WIMS, to support student's learning, recall Von Neuman's quote: *Young man, in mathematics you don't understand things. You just get used to them.* WIMS, when well used, appears to be a tool that can make the *getting used to* much easier.

[1] Interactive map showing where WIMS is used. http://downloadcenter.wimsedu.info/download/map/map2.html

[2] Enquête auprès des utilisateurs WIMS http://moin.irem.univ-mrs.fr/groupe-wims/Enquete [consulted 2017/09/14]

[3] Le professeur Xiao Gang, créateur du logiciel WIMS s'est éteint le vendredi 27 juin 2014 http://unice.fr/fil/service-communication/actualites/le-professeur-xiao-gang-createur-du-logiciel-wims-s2019est-eteint-le-27-juin-2014

[4] WIMS EDU site http://wimsedu.info

[5] To see some examples of WIMS, connect to a WIMS-server, for instance http://wims.auto.u-psud.fr/wims/?lang=fr. You can change the language but the french version is the richest one. Then explore some *classes ouvertes* as a *visiteur anonyme*.

REFERENCES

Berland, C. (2017) *E-learning platform WIMS for bachelor first year courses on electric circuit.* Presented at EAEEIE Annual conference 2017, Grenoble, Fr.

Cordier, F. & Cordier, J. (1991). L'application du théorème de Thalès. Un exemple du rôle des représentations typiques comme biais cognitifs. *Recherche en didactique des Mathématiques*, 11(1), 45-64.

Ganier, F (2016). *C'était pourtant écrit !!! Pourquoi est-il si difficile de comprendre des instructions?* Presented at WIMS EDU colloque 2016, Annecy, Fr. http://webcast.in2p3.fr/videos-pourquoi_est_il_si_difficile_de_comprendre_des_instructions

Giner, E. & Kobylanski, M. (2017). *Retour sur l'expérimentation WIMS*. Research Report. UPEM.

Houdé, O. (2014). *Le raisonnement.* Que Sais-je ? PUF.

Jacquemin, L. (2017). *Enquête sociologique auprès d'utilisateurs enseignants de WIMS sur leurs usages et pratiques effectives.* Research Report. UPEM.

Khaneman, D. (2011). *"Linda: Less is More". Thinking, Fast and Slow*. New York: Farrar, Straus and Giroux. pp. 156-165.

Kobylanski, M. (2015). Plates-formes d'apprentissage et WIMS. *Gazette des Mathematiciens*, (145), 47-51.