A COOPERATION BETWEEN A HIGHER EDUCATION INSTITUTION AND A SECONDARY SCHOOL: SOME RESULTS AND CONCLUSIONS

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Abstract. *Since the society and the world in general continues to become more sophisticated technological and engineering applications, it is imperative that students should be prepared to enter into the workforce with the skills and levels of knowledge capable of sustaining such progress. As such, the need for students to become aware of such disciplines of engineering during their secondary school years is increasingly critical. The main goal of this paper is to shown how it is possible to increase the interest of the secondary students in the disciplines of the Engineering area.*
This paper draws upon ongoing collaborative project between one higher institution education (University of Minho) and a secondary school (Instituto Nun'Alvres), in Portugal. The specific goals of the project are: (i) to promote a more experimental teaching in connection with the national economic priorities, (ii) to develop the ability to technical and scientific research and innovation amongst the youth, (iii) to foster the interest and motivation for technical area among higher education candidates.
The project reported in this paper included six secondary students in total, three secondary school teachers and six engineering teachers from the University of Minho. Each of the students developed his own project, which includes wide diversity of tasks according to the different phases of project. In this paper, assessment procedures will be discussed namely: the evaluation, taking place during the project and the final evaluation, which includes an oral presentation and a written report.
Overall, the broad project was interesting from secondary students' opinion and demonstrated to be benefit for both institution parts. As a natural consequence of this success work, similar projects between the University of Minho and other secondary schools will be conducted in the near future.

Keywords*: University, Secondary School, Partnership, Engineering Education*

1. INTRODUCTION

Since the society and the world in general continues to become more sophisticated technological and engineering applications, it is imperative that students should be prepared to enter into the workforce with the skills and levels of knowledge capable of sustaining such progress. As such, the need for students to become aware of such disciplines of engineering during their secondary school years is increasingly critical (Johnston, Wetherill and High, 2002). On the other hand, the constant changes in the industrial and social world, such as the migration of countless companies, are also very important challenge for the new generations, namely, the actual youth (Allan, 2005). Therefore, the University of Minho has celebrated a collaborative program with a secondary school (Instituto Nun'Alvres) in order to promote the science and technology among the young students. The ultimate goal of this partnership is to help instill an interest, and thus a desire, for students to potentially purse higher education in science and engineering related fields. In addition to this collaboration between University of Minho and secondary school, a number of other indicatives have been taken in order to show the main scientific and pedagogical activities that are currently developed at the University of Minho, in special at the Mechanical Engineering Department. Visits to secondary schools, Summer University, open week university, special lessons and thematic sessions are examples of the activities promoted by the University of Minho.

The main purpose of this work is to present the project and to promote a more experimental teaching in connection with the national economic priorities, to develop the ability to technical and scientific research and innovation amongst the youth and to foster the interest and motivation for technical area among the higher education candidates. The project reported in this paper included six secondary students in total, three secondary school teachers and six engineering teachers from the University of Minho. Each of the students develops his own project, which includes wide diversity of tasks according to the different phases of project. In this paper, assessment procedures will be discussed namely, the evaluation taking place during the project and the final evaluation, which includes an oral presentation and a written report. This collaboration is expected to be helpful for educators and students to choice the higher school degree and, ultimately help students better for entrance into society. The remaining of the paper is organized as follows. In section two the general motivation for this work is presented. A short description of the protocol is given in section three. One example of students' projects is presented in section four. Finally, in last section, the main conclusions from this work are drawn and the perspectives for future research are outlined.

2. MOTIVATION FOR THIS WORK

The qualification of the Portuguese population has been identified as playing a crucial role in the social and economic development indispensable to continue the sustained development. This desideratum is essential for the improvement of the life conditions and safety of populations, which should reach the average of the other countries of the European Union. The European Union has been defined goals that intend to ensure that the European space becomes economically more competitive and intensify the capability of economic and social development. The *Innovation* and *Knowledge* were identified the sustentation pillars for this process and the motors for its implementation (Akay, 2003, De Graff and Christensen, 2004). To the University, as agent of creation of the knowledge and support and promotion the valorization of the knowledge chain, is attributed the mission to better concretize these objectives and to contribute to define the requisites that ensure the concretization of those objectives (see UNESCO report, 2000).

Indeed, the science, technology and innovation and the way how the universities and society, in general, use and disseminate the knowledge has assumed a crucial importance over the last few years. The system of science and Portuguese technology is in a convergent path with the average of European Union. However, the absolute values of the Portuguese reality are still reduced. For instance, for the year 2001, in Portugal the number of researchers per thousand of active population was equal to 3.4 against 5.3 of European Union (see CRUP report). Nevertheless, over the last years an evolution accentuated is verified thanks to scholarships programs promoted by the Portuguese Foundation for Science and Technology, which allowed the growth of the number of graduates and investigators in the scientific and technological fields.

The promotion and popularization of the scientific culture allow to the citizens a perception based in scientific bases of the world in that they live and of the society of the knowledge in that they are inserted. The promotion of the science for population, in general, and for the secondary school, in special, is of extreme importance, for being decisive for the capacities formation of scientific learning that they will be able to used along the life, and also for the importance of fomenting a critical spirit and of experimentation in the appropriation of the scientific culture.

This has been an important topic also analyzed and discussed in other countries such in the USA (Gidleya and Hampsona, 2004). Furthermore, the American Society of Mechanical Engineers (ASME) presented a work to promote a shared vision for the future mechanical engineering education in the context of new and rapidly emerging technologies and disciplines, national and global trends, societal and challenges for the 21st century, and associated opportunities for the profession. The ASME states that "Innovation in mechanical engineering education will prepare graduates to pursue their individual professional interests well beyond perceived boundaries associated with the discipline's traditional roles, in keeping with the current and future applications and associated flexibility of the profession. In this way mechanical engineering will attract the best and the brightest students and faculty, including women and other traditionally underrepresented groups, many of whom may not otherwise consider entering the profession" (see ASME report, 2004). In addition, the ASME report emphasized that "a broad consensus has been developed about the need for a critical reexamination of engineering education in the context of the accelerating pace of change in society and the workplace. Among the factors that provide compelling reasons for this reexamination are: (*i*) the growing complexity and interdisciplinary foundations of engineering systems; (*ii*) the rapid emergence of new technologies; (*iii*) globalization as a principal driving force for change, accompanied by increasing global competition; (*iv*) prospective students' interests that go well beyond perceived boundaries associated mechanical engineering's traditional roles" (see ASME report, 2004).

The primary aims of this program celebrated between University of Minho and Instituto Nun'Alvres are: (i) to promote a more experimental teaching in connection with the national economic priorities, (ii) to develop the ability to technical and scientific research and innovation amongst the youth, (iii) to foster the interest and motivation for technical area among higher education candidates.

3. PROTOCOL BETWEEN UNIVERSITY OF MINHO AND INSTITUTO NUN'ALVRES

3.1. General description

In this section the protocol celebrated between University of Minho and Instituto Nun'Alvres is presented in detail. The program includes a general meeting on the first week. During this meeting, the University of Minho informally presents the projects to be developed by each secondary school student. The projects are briefly introduced to all students so that they can choose the one they prefer. All the projects proposed are within the scientific and didactic activities developed at the Department of Mechanical Engineering of University of Minho. Furthermore, an important part of the projects deals with the computing science because the secondary school students are from the computing area and one the goal of this pilot project is to be an application of their knowledge to other fields such as mechanical engineering. In addition, during the first week of program, a general visit to Department of Mechanical Engineering is performed in order to show all students the laboratory facilities and the research work that exists at the department. Thus, the students can better understand what Mechanical Engineering is and it is related with computer and software science. This pilot program includes six secondary students. Their secondary teachers according to their own criteria

and taking into consideration the students' interests make the selection of students. An efficient students selection process is critical for a successful experience.

The protocol celebrated between University of Minho and Instituto Nun'Alvres is based on the following premises:

- the teaching system should be understood as a set of resources through which the right to the education is concretized;
- this right should be developed with base of several structures and actions and under the responsibility of different institutions;
- more and more it is necessary to promote the engineering courses near the secondary students;
- one of missions and vocations of the University of Minho is to render services at the involving community, in general, an at the secondary schools, in particular;
- the secondary schools need for technological and library resources capable to turn their teaching system more attractive to the students.

3.2. Detailed description

The terms that govern the protocol University of Minho-Instituto Nun'Alvres are listed below;

1. *Purposes*
   - the present protocol has as objective the cooperation between the two granting in order to congregate the efforts tending to create dynamism at the teaching system and to touch the students of Instituto Nun'Alvres for the graduate courses of the University of Minho;
   - the University of Minho indents to give technical, scientific and didactic support to Instituto Nun'Alvres;
   - the University of Minho allow access to the library of the teachers of the Instituto Nun'Alvres;
2. *Application form*
   - the intervention of both part should be properly formalized by one of the parts and authorized by the other one;
   - within the constraints resulting from the annual schedule of the teaching activities of the University of Minho, it is given maximum cooperation to Instituto Nun'Alvres in order to offer their students thematic lessons and visits to the University of Minho laboratories;
   - Lectures and other interventions of the University of Minho members should always be integrated in the Instituto Nun'Alvres activities;
3. *Attendance/Accompaniment*
   - the accompaniment of the present protocol and annual schedule is done by a mixed committee defined by University of Minho and Instituto Nun'Alvres;
   - the duration of the committee members is one year and is successively and automatically renewed while there is no deliberation in opposite for one of the parts;
4. *Protocol duration and formalization*
   - the present protocol is valid for two years and is automatically renewed if it is not denounced by any of the parts;
   - the actions resulting from the present protocol are properly formalized through addenda that should consist of action description, objectives, periods and dates of realization, team constitution and the indication of the organic units involved, identification of the responsible members by the coordination and others relevant specifications.

It was also celebrated an addendum to the protocol between the University of Minho and the Instituto Nun'Alvres in the sense of the conjugation of efforts to reach the following statements:

- to contribute for a teaching more experimental and connected with the reality of the national economy;
- to contribute to develop innovation capacities and technical and scientific investigation in the layers more youths of the population;
- to promote and motivate, in a close future, the students of the technological areas for the entrance in the academic degrees of the University of Minho.

The terms that govern the addendum to the protocol are listed below;

1. *Partners*
   - the School of Engineering, through its Department of Mechanical Engineering intends to receive between January and May of 2005, six students of Instituto Nun'Alvres of the Computation professional course, of the twelve year of secondary school, to perform their professional apprenticeship;
2. *Main objectives, conditions and parameters that characterize the apprenticeships*
   - to develop the creativity and the permeability of the trainee to the technical and scientific innovation;

- to complete the trainee's technician-scientific formation relating the previous knowledge of the same with current investigation works in Department of Mechanical Engineering;

3. *Specific objectives*
   - to define for the responsible teachers of Department of Mechanical Engineering for the proposition of each apprenticeship;
4. *Duration*
   - the duration of the apprenticeships is of five months, beginning on January of 2005;
5. *Attendance/Accompaniment*
   - the Instituto Nun'Alvres, designate one or more responsible teachers for the trainee's attendance. They visit the Department of Mechanical Engineering at least twice during the apprenticeship;
   - at the Department of Mechanical Engineering, the teacher(s) that propose an apprenticeship are responsible for the academic-scientific trainee's;
   - The student trainee, weekly, gives to know to the responsible teachers (of Department of Mechanical Engineering and of Instituto Nun'Alvres) the performed work in that week and will adjust the evolution of his work according to teachers' feedback;
   - Department of Mechanical Engineering assumes the responsibility to create all of the necessary work conditions for the successes of the apprenticeship works proposed;
   - the student's trainees are considered as external readers of the Libraries of the University of Minho, without any taxes;
6. *Classification*
   - the evaluation along the apprenticeship is based on qualitative parameters existing in a grill, previously elaborated for the teachers of Instituto Nun'Alvres that it is of the student's knowledge;
   - at the end of the apprenticeship, after public presentation and after appreciation of a report corresponding to the performed work, all the responsible teachers (of Department of Mechanical Engineering and of Instituto Nun'Alvres), of each work, they will attribute a quantitative classification (rang from 0 to 20 values). The final note will be the average of the classifications attributed by teachers of Department of Mechanical Engineering and of Instituto Nun'Alvres, with equal weight;
7. *Others*
   - the traineeship takes place is in the facilities of Department of Mechanical Engineering, which are at the Campus of Azurém, in Guimarães;
   - the apprenticeship doesn't have vinculum character; Department of Mechanical Engineering doesn't assume to integrate the student trainee in their own services, when finish the apprenticeship;
   - the apprenticeship is not subject to any remuneration type;
   - in the dislocations Instituto Nun'Alvres/Department of Mechanical Engineering or vice-versa, the trainee is covered for the school insurance of Instituto Nun'Alvres.

4. EXAMPLE OF A PROJECT

This example is illustrative of the type of works that the secondary school students can develop. These works have two purposes that are, in first hand, to promote the secondary school students in contact with a new experience of small works development in the scope of large research projects and, in second hand, to allow that the research projects where these works are inserted can evolve of faster and efficient way.

4.1. Context of the work

In the Automation group of the Mechanical Engineering Department of the University of Minho are, now, in development some works related with formal methods, more precisely in its use for the guarantee of the safety behavior of automated systems. These safety systems are called "Dependable Systems".

The dependability has, as main goal, to answer to the requirements of reliability, availability, and maintainability of automation systems. For its direct impact on the people and goods safety, the reliability of the critical systems (transports, space, nuclear,...) has, since some time, mobilized the efforts of the scientific community. To assure the safety of a system, it is necessary to use a global approach (to guarantee that it not exists weaknesses) that takes into account a set of engineering activities and, later, after entering in functioning, the set of activities of exploitation and maintainability in conditions of operational exploitation of the system. Therefore, the scientific community makes an effort to find, for the engineers, models, methods and tools, considering the different parts of an automation system.

In this context, of permanent search of the safety functioning of automated systems, there are certain formalisms that can be used with the purpose "of helping" the engineers to get and to guarantee the demanded requirements for correct behavior of these systems. Between the several tools used on increasing automation systems dependability we highlight the FMEA (Stamatis, 1995), redundancy and fault tolerance (Avizienis, 1995) related with the plant analysis; the supervision theory (Crockett *et al*. 1987) and the non model-based formal verification (Moon, 1994) related with the

controller analysis; the diagnosis (Lunze *et al.* 2001) and model-based formal verification (Machado *et al.* 2006) related with the whole system analysis.
The systems that we intend to analyse are automation systems composed by a plant and a discrete event controller (both enhancing logic signals) and our goal is to research on formal verification (model-based and non model-based) to determine the best approach for increase system dependability.

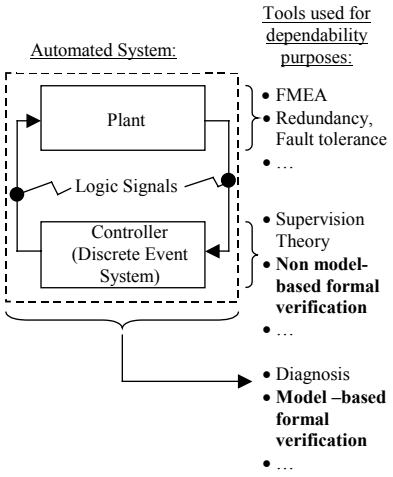

Figure 1. Tools/methods used for dependability purposes according the different parts of an automation system.

In this case, it is used the formal verification (non model-based and model-based) by model-checking technique. Between the problems inherent when using model-checking, the choice to proceed at the verification of the controller properties taking into account, or not, a controlled plant model is, many times, difficult.

It is, therefore, that we consider one technique of construction of behavior models for controlled industrial systems, having as main goal the controller verification. For this, it has been adopted a modular approach and it has been used an adapted class of automaton (Machado, 2006) that is used to model all the system.

With our approach we consider two cases:

- The system model is composed, only, by the controller model (non model-based approach);
- The case where the system model is composed by the controller model connected with the plant model (model-based approach);

With the scope of formal verifying the models, it is necessary that, in first hand, they are simulated, therefore this simulation allows, in a simple and friendly way (appealing to graphical representations), to eliminate most of the errors of these systems behavior. As tool used for simulation it is used UPPAAL software (UPPAAL, 2006) and as tool for the formal verification it is used the model-checker NuSMV (NuSMV, 2002).

Although the UPPAAL software may be used, also, as model-checker, the results that it will be able to obtain are limited (in terms of answer times), therefore this work deals with discrete systems and the UPPAAL tool was developed for dealing with timed systems.

In the procedure of formal verification, we create the models in UPPAAL software, with a friendly graphical edito; we simulate these models there; and, then, we translate them for the input code of the NuSMV software (file .txt). As this conversion takes a lot of time, when executed manually, it is necessary an informatics application that do this translation automatically, so the necessity and the context of this work.

4.2. Description and summary of the work

As this work is complex, we decided that it was pertinent that this project was executed, in group, for two secondary school students. This decision is a consequence of a vast and complex set of domains that the students must to understand before the beginning of this work. Thus, the main topics related with the Project are the following:

Title: Automatic translation of finite state automata, modeled by UPPAAL, for the NuSMV input code using Python programming language (Python 2006).

Description: Taking into account that UPPAAL software is based on XML (XML 2007) and that any graphical model simulated with UPPAAL can be translated automatically in XML, the intended work, for the secondary school student, is the development of an informatics application for the automatic translation of the XML file, generated automatically by UPPAAL, on the NuSMV input code (.txt file). The adopted programming language was Python because is a high level language well adapted with text dealing.

Objective of the work: The main goal of this project is to develop a computational program, in Python programming language, to perform automatically the .txt file presented in Fig. 4 that is the result of the conversion of the XML file presented in the Fig. 3.

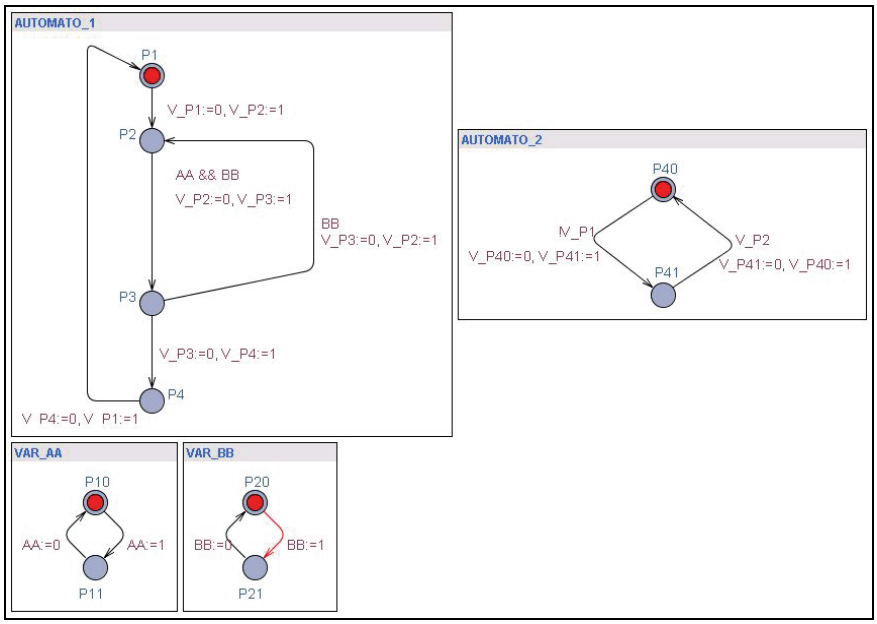

Figure 2. UPPAAL graphical representation of a case study.

The UPPAAL model of the case study, that is presented in Fig. 2, has as basis the XML file which extract is presented in Fig. 3.

```
    ...
  </location>
- <location id="id1" x="160" y="128">
    <name x="128" y="112">P2</name>
  </location>
- <location id="id2" x="160" y="288">
    <name x="128" y="272">P3</name>
  </location>
- <location id="id3" x="160" y="384">
    <name x="176" y="368">P4</name>
  </location>
  <init ref="id0" />
- <transition>
    <source ref="id0" />
    <target ref="id1" />
    <label kind="assignment" x="176" y="88">V_P1:=0, V_P2:=1</label>
  </transition>
- <transition>
    <source ref="id1" />
    <target ref="id2" />
    <label kind="assignment" x="184" y="176">V_P2:=0, V_P3:=1</label>
  </transition>
- <transition>
    <source ref="id2" />
    <target ref="id3" />
    <label kind="guard" x="176" y="312">AA && BB</label>
    <label kind="assignment" x="168" y="328">V_P3:=0, V_P4:=1</label>
  </transition>
    ...
```

Figure 3. Extract of the XML file automatically generated from the UPPAAL model presented in Fig.2.

The XML file presented in Fig. 3 is the basis for the NuSMV code presented in Fig. 4. The advantage of this work is to allow the automatic generation of this .txt file. That informatics application allow the Mechanical Engineering Researchers a faster elaboration and execution of the models to be tested by NuSMV.

```
MODULE main

IVAR
        FR : 1..7;

        AA : boolean;
        BB : boolean;


--****************************************
--****************************************
--****************************************
--AUTOMATO 1
VAR
        AUT1 : {P1, P2, P3, P4};
DEFINE
        V_P1 := AUT1=P1;
        V_P2 := AUT1=P2;
        V_P3 := AUT1=P3;
        V_P4 := AUT1=P4;

ASSIGN
        init(AUT1) := P1;
        next(AUT1) := case
                AUT1=P1 & FR=1 : P2;
                AUT1=P2 & FR=2 : P3;
                AUT1=P3 & BB & FR=3 : P2;
                AUT1=P3 & AA & BB & FR=4 : P4;
                AUT1=P4 & FR=5 : P1;
                1 : AUT1;
                esac;


--AUTOMATO 2

VAR
        AUT2 : {P40, P41};

DEFINE
        V_P40 := AUT2=P40;
        V_P41 := AUT2=P41;

ASSIGN
        init(AUT2) := P40;
        next(AUT2) := case
                AUT2=P40 & !V_P1 & FR=6 : P41;
                AUT2=P41 & V_P2 & FR=7 : P40;
                1 : AUT2;
                esac;
```

Figure 4. Desired final NuSMV file (corresponding of the case study presented in Fig. 2) after automatic translation of the XML file that is presented on Fig. 3.

Basic knowledge: Since the work is to be developed with Python programming language, the students should be able to design computational algorithms and expertise in computation.

Work plane: This project includes twelve main tasks that are summarized in what follows:

1. Bibliographical revision about finite state machines;
2. Bibliographical revision about UPPAAL and elaboration of some basic models with UPPAAL;
3. Bibliographical revision about XML and elaboration of some basic models with XML;
4. Bibliographical revision about Python and elaboration of some basic models with Python;
5. Bibliographical revision about NuSMV and elaboration of some basic models with NuSMV;
6. Study of a simple “case study” (linear pneumatic actuator);
7. Modeling the case study with UPPAAL;
8. Reading of the UPPAAL model (in XML) and its translation (using Python programming language) to NuSMV input code;
9. Systematization of all the procedures indicated in the tasks 7 and 8.
10. Automatization of all the procedures related with the tasks 7 and 8.
11. Written a technical report (up to 30 pages) which contains the work performed by the student;
12. Oral presentation of the produced work.

Supervision: The students develop his own work under the supervision of two teachers, one from the University of Minho and another one from Instituto Nun’Alvres.

The chronogram and schedule containing the tasks of this project can be summarized in the Tab. 1, for the two students involved in the project.

Table 1. Chronogram containing the tasks of the two student's project.

Student 1

	1st month				2nd month				3rd month				4th month				5th month			
	week				week				week				week				week			
Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

Student 2

	1st month				2nd month				3rd month				4th month				5th month			
	week				week				week				week				week			
Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				

4.3. Obtained results

The main obtained results are traduced as a Python program that translates any XML file to the NuSMV input code. An extract of this Python program is presented in Fig. 5. The translation rules were defined by the supervisor of this work that belongs to the Mechanical Engineering Department of the University of Minho.

```
class Printer(HtmlEasyPrinting):
        def __init__(self):
            HtmlEasyPrinting.__init__(self)

        def GetHtmlText(self,text):
            "Simple conversion of text.  Use a more powerful version"
            html_text = text.replace('\n\n','<P>')
            html_text = text.replace('\n', '<BR>')
            html_text = html_text +'<br><small><i> Created By Jorge Ramos </i></small><br>'
            return html_text

        def Print(self, text, doc_name):
           self.SetHeader(doc_name)
           self.PrintText(self.GetHtmlText(text),doc_name)

        def PrintPreview(self, text, doc_name):
           self.SetHeader(doc_name)
           HtmlEasyPrinting.PreviewText(self, self.GetHtmlText(text))


#-----------------------------------------------------
class MyChild(wx.MDIChildFrame):

        #-----------------------------------------------------------
        """Esta função cria 1 Child Frame."""
        #-----------------------------------------------------------

        def __init__(self,parent,path=""):
                dlg = wx.FileDialog(parent,message="Choose a file", defaultDir=os.getcwd(),defaultFile="", wildcard=wi
                if dlg.ShowModal() == wx.ID_OK:
                        self.pth = dlg.GetPath()
                        self.path=dlg.GetFilename()
                dlg.Destroy()
                wx.MDIChildFrame.__init__(self,parent,-1,self.path,(-1,-1),(350,500), style = wx.MAXIMIZE)
                self.t=wx.TextCtrl(self,-1,"",size=(125,-1),style=wx.TE_MULTILINE  | wx.TE_READONLY )


        def run(self):
                from xml.dom import minidom
                global numeros
                numeros=0
```

Figure 5. Extract of the Python program that translates any XML file to NuSMV input code, according to the established rules.

5. CONCLUSIONS AND FUTURE WORK

In the accomplishment of this work it was evidenced that the students involved had developed knowledge and capabilities for its future ingression in an institution of superior education. Beyond the knowledge that they had acquired, it was shown, to them, the reality of work developed with an institution of superior education and it was infused, in these students, the motivation for the scientific work. The work that they had developed was used in a research project of bigger interest and it was demonstrated that the abilities of these secondary school students can be developed in a context of scientific research area. In this domain, they had the first contact with this reality in domains related with Engineering and Technology.

As immediate future cooperation between the two institutions, there are, already, defined other forms of cooperation, as, for example, the creation of Courses of Technological Specialization, that will be proposed by the two institutions, together, to the Portuguese Ministry of Science, Technology and Superior Education. These courses of Technological Specialization are essentials for the development of the Portuguese Economy; therefore they allow one strong technological education for the companies' technicians of Portugal.

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