Learning and teaching in higher education – a study with Science Food Engineering students

Sónia PAIS[1] *(Superior School of Tourism and Sea Technology, Leiria's Polytechnical Institute, Portugal)* – sonia.i.pais@ipleiria.pt

Isabel CABRITA *(Department of Education, University of Aveiro, Portugal)* – icabrita@ua.pt

António BATEL ANJO *(PmatE, University of Aveiro, Portugal)* – batel@ua.pt

Abstract

Nowadays we live in an ever-changing society; changes that are reflected, not only, but also, in the educational community. Thus renewal of paradigms in the educational context is demanded. The challenge that teachers face today is to motivate students to learn, get them to commit to and have an active role in their learning, thus increasing their motivation to learn. The questions underlying this work are: *How can teachers know the students' differences and their individual learning characteristics? How can teachers understand their students and design effective instruction? What teaching strategies are recommended to help teachers meet the different learning needs of all their students?* The empirical part of the case study, in an investigation-action context, encompassed students of the curricular unit of Mathematical Analysis I (2008/2009 1st semester), of the plan of studies of the Science Food Engineering of the Superior School of Tourism and Sea Technology (ESTM), of Leiria's Polytechnical Institute. Preliminary analysis of the data collected through several techniques – surveys, content analysis and participant observation – indicates that instruction designed to address a broad spectrum of learning styles has proven more effective than traditional instruction (almost exclusively magisterial and based on the transmission of knowledge), which focuses on a narrow range of styles. Moreover, it allows us to reflect on the conditions that will enhance the implementation of a model that has the learning of the students as the basis, respecting their individual rhythm and learning style preferences, and favoring an education centered in the pupil's body of work.

Keywords: Learning Styles; Teaching Strategies; Students Differences; Effective Teaching

1. Introduction

Nowadays we live in an ever-changing society. The educational context is no exception, and requires a renewal of paradigms. Profound changes to the role and function of the professor and the students are particularly vital (Costa, Santos & Simão, 2003; Cowan, 2002; Light & Cox, 2001; Morin, 2002). "*The teacher must abandon as much as possible, the traditional expositive method, where the role of the students is almost one hundred percent passive*" (Sebastião e Silva, 1975, p.11).

In Biggs' opinion (1999, p.11), *"the key to reflecting on the way we teach is to base our thinking on what we know about how students learn."*

The current University students have different motivations, different attitudes about teaching and the learning process, and different responses to specific classroom environments and instructional practices. The more thoroughly teachers understand the differences, the better chance they have of meeting the diverse learning needs of all their students.

An important aspect of student diversity is the difference in students' learning styles. Students have different ways of appropriating and processing the information (Entwistle et al, 2000; Felder & Brent, 2005; Kolb & Kolb, 2003), and they learn more and better when information is presented to them in their preferred mode (Felder & Brent, 2006).

The challenge that teachers face today is to motivate students to learn, get them to commit to and have an active role in their learning, thus increasing their motivation to learn.

[1] Address for correspondence: Sónia Isabel Pais, Escola Superior de Turismo e Tecnologia do Mar, Instituto Politécnico de Leiria, Santuário Nª Srª dos Remédios, 2520-641 Peniche, Portugal (Phone: 00351 934 280 583; Fax: 00351 262 783 088; E_mail: paissoni@gmail.com)

2. Learning Styles

"Learning styles are characteristics cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Felder & Brent, 2005, p. 58). However, these do not only affect the way people learn, but also their way of being and acting in different dimensions of life (Kolb, 1984), influencing the way individuals act in a group, relate to each other, participate in activities and solve problems.

In Felder & Brent opinion's (2005, p. 58), one learning style is neither preferable nor inferior to another, but is simply different, with different characteristic strengths and weaknesses.

Learning styles have been widely studied since the 1920s (Jung, 1921), but it was from mid-twentieth century that took the biggest development in this area (Baker, Jensen & Kolb, 2002; Entwistle, McCune & Walker, 2000; Felder & Brent, 2005; Felder & Silvermann, 1988; Jonassen & Grabowski, 1993; Kolb, 1984; Kolb & Kolb, 2006; Richardson, 2005).

The concept of learning styles is not universally accepted. The range of theoretical points of view and the lack of conceptual integration is remarkable, making it difficult to find a single definition of learning style. Thus, there is a plurality and diversity of definitions of this concept (Biggs, 1985; Entwistle, 1981; Keefe, 1979; Kolb, 1984). Many authors emphasise different aspects: some focus on behavioural characteristics, others on the process or the structure inferred from the behaviour; for some, the learning style emerges from a set of characteristics and for others forwards for a specific typology of people segments. In Almeida's opinion (2007, p.60), taking into account different definitions of the concept in the literature, "learning style matches to a hypothetical construct that researchers use to, firstly, emphasize the regularities observed in the student's behaviour while learning and, moreover, to emphasize the differences between a student from one another".

Several dozen models of learning styles have been developed, five of which have been extensively applied to engineering. One of the best known is Felder and Silverman's learning style model.

2.1 The Felder-Silverman Model

"A learning-style model classifies students according to where they fit on a number of scales pertaining to the ways they receive and process information" (Felder & Silverman, 1988, p. 674).

Students have different learning styles. Some students tend to focus on facts, data, and observable phenomena; others are more comfortable with theories and abstractions; some respond strongly to visual presentation of information, like pictures, diagrams, and schematics; others prefer verbal explanations – written and spoken; some prefer active and interactive learning; others prefer to learn introspectively and individually. However, functioning effectively as professionals requires working well in all learning style modes. If professors teach exclusively in theirs students' preferred modes, the students may not develop the mental agility they need to reach their potential for academic and professional achievement Although, if professors teach exclusively in a manner that favours their students' less preferred learning style modes, the students' lack of interest may be large enough to interfere with their learning. Thus, a goal of education should be to help students build their skills in both modes of learning: the preferred and the less preferred. Felder and Silverman proposed a model to define the different learning styles (Table 1). This model was developed in order to be applied to teaching in engineering courses. According Felder and Brent (2005), a student's learning style may be defined by the answers to four questions:

- What type of information does the student preferentially perceive: *sensory* (sights, sounds, physical sensations) or *intuitive* (possibilities, memories, thoughts, insights, hunches)?
- What type of sensory information is most effectively perceived: *visual* (pictures, diagrams, flow charts, graphs, demonstrations) or *verbal* (written and spoken explanations)?
- How does the student prefer to process information: *actively* (through engagement in physical activity or discussion) or *reflectively* (through introspection)?
- How does the student characteristically progress toward understanding: *sequentially* (in a logical progression of incremental steps) or *globally* (in large 'big picture' jumps, holistically)?

Table 1 – Dimensions of Learning Styles

Perception	
Sensing Learners (S)	*Intuitive Learners (N)*
Focus on external input (see, hear, taste, touch, smell)	Focus on internal input (thoughts, memories, images)
Practical	Imaginative
Observant (notice details of environment)	Look for meanings (miss details)
Concrete thinking (facts, data, hands-on work)	Abstract thinking 8theories, math models)
Learn through repetition (drills, numerous examples, replication of experiments)	Like variety in learning experiences (bored with repetition)
Methodical	Quick
Like working with details	Like working with concepts
Complaint about courses: No apparent connection to real world	Complaint about courses: 'Plug & Chug' (Lots of memorization, repetitive formula substitution)
Problem with exams: Run out of time	Problem with exams: Careless mistakes
Input Modality	
Visual Learners (Vs)	*Verbal Learners (Vb)*
'Show me.' • Pictures • diagrams • sketches • schematics • flow charts • plots	'Explain it to me' • spoken words • written words, symbols (seen, but translated by brain into their oral equivalents)
Processing	
Active Learners (A)	*Reflective Learners (R)*
Tend to process actively (doing something physical with presented material, then reflecting on it)	Tend to process reflectively (thinking about presented material, then doing something with it)
Think out loud	Work introspectively
'Let's try it out and see how it goes.'	'Let's think it through and then try it.'
Tend to jump in prematurely	Tend to delay starting
Like group work	Like solo or pair work
Understanding	
Sequential Learners (Sq)	*Global Learners (G)*
Build understanding in logical sequential steps	Absorb information randomly, then synthesize the big picture
Function with partial understanding of information	Need the big picture (interrelations, connections to other subjects and personal experience) in order to function with information
Make steady progress	Large leaps in understanding with little progress between them
Explain easily	Can't explain easily
Good at analytical thinking (the trees)	Synthesis, holistic thinking (the forest)

Source: Felder & Brent, (2006, p. A3).

2.2 Learning and Teaching Style Mismatches

If students learn in many ways, teaching methods also vary. Some instructors mainly lecture, others demonstrate and spend time on activities; some concentrate on principles and others on applications; some put emphasis on memory and others on understanding. How much a student learns in a class is governed not only by that student's native ability and prior preparation (student's background) but also by the compatibility of the student's attributes as a learner and the instructor's teaching style (Felder and Brent, 2005).

Table 2 – Dimensions of Learning and Teaching Styles

Preferred Learning Style		*Corresponding Teaching Style*	
sensory int uitive	perception	concrete abstract	content
visual verbal	input	visual verbal	presentation
active reflective	proces sin g	active passive	student participation
sequential global	unders tan ding	sequential global	perspective

Source: Felder & Silverman, (1988, p. 675).

In recent decades, the majority of engineering courses have been offered based on an verbal, passive, sequential and intuitive basis approach. However, this teaching style is inadequate for the learning style of most engineering students. Felder & Brent (2006) refer to some of these discrepancies:

- Most students are sensors, while most teachers tends to guide their teaching style toward intuitors, emphasizing theory, 'fundamentals' and mathematical models over experimentation and practical applications;
- Most students are visual learners, while most of course content is overwhelmingly verbal, emphasising lectures and readings over demonstrations and visual illustrations;
- Although all classes have both active and reflective learners, most engineering students are active. However traditional engineering instruction tends to be passive (lectures and readings are the principal vehicles for transmitting information);
- Most students are sequential and traditional engineering education (instructors, courses, textbooks) is sequential. However, global students (those who are multidisciplinary thinkers) are an extremely important minority.

Consequences of these mismatches are several and important: poor student performance, professorial frustration, and society potentially loses excellent engineers (Felder & Silverman, 1988). Most students can't get what is being taught. In consequence, they may then lose their interest and become inattentive in class, do poorly on tests, and get discouraged. In Felder & Brent's opinion (2005), in this situation, teachers feel frustrated and have one of two attitudes: defensive becoming overly critical of their students (making things even worse) or wonder if they are in the right profession.

2.3 Teaching Techniques to Adress All Learning Styles

It is under a teacher's control to organize his/her teaching method, defining strategies in which all the different styles are covered. Thus, the difference between teaching style and learning style will decrease, allowing all individual students' needs to be satisfied. The teacher who adapts his teaching style to include both poles of each of the given dimensions should come close to providing an optimal learning environment for most students in a class.

There are 16 (2^4) learning styles in the model proposed by Felder and Silverman.[2] The teacher should not be intimidated by the prospect of trying to accommodate 16 different styles in a given class, because the inclusion of a relatively small number of teaching techniques to an instructor's repertoire should be sufficient to accommodate the learning styles of most, if not all students, in any class. The several teaching techniques proposed in Table 3 allow the teacher to address all learning styles in his classes, covering the full spectrum of learning needs of all his students.

Table 3 – Teaching Techniques to Address All Learning Styles

Teaching Techniques to Address All Learning Styles
• Motivate learning. As much as possible, relate the material being presented to what has come before and what is still to come in the same course, to material in other courses, and particularly to the students' personal experience *(global).*
• Provide a balance of concrete information (facts, data, real or hypothetical experiments and their results) *(sensing)* and abstract concepts (principles, theories, mathematical models) *(intuitive).*
• Balance material that emphasizes practical problem-solving methods *(sensing/active)* with material that emphasises fundamental understanding *(intuitive/reflective).*
• Provide explicit illustrations of intuitive patterns (logical inference, pattern recognition, generalization) and sensing patterns (observation of surroundings, empirical experimentation, attention to detail), and encourage all students to exercise both patterns *(sensing/intuitive).* Do not expect either group to be able to exercise the other group's processes immediately.
• Follow the scientific method in presenting theoretical material. Provide concrete examples of the phenomena the theory describes or predicts *(sensing)*; then develop the theory or formulate the mod *(intuitive/sequential)*; show how the theory or mod can be validated and deduce its consequences *(sequential)*; and present applications *(sensing/sequential).*
• Use pictures, schematics, graphs, and simple sketches liberally before, during, and after the presentation of verbal material *(sensing/visual).* Show films *(sensing/visual).* Provide demonstrations *(sensing/visual)*, hands-on, if possible *(active).*
• Use computer assisted instruction if you have software that allows for experimentation and provides feedback *(sensing/active).*
• Provide small intervals for students to think about what they have been told *(reflective).*
• Provide opportunities for students to do something active besides transcribing notes *(active).*
• Assign some drill exercises to provide practice in the basic methods being taught *(sensing/active/sequential)* but do not overdo them *(intuitive/reflective/global).* Also provide some open-ended problems and exercises that call for analysis and synthesis *(intuitive/reflective/global).*
• Give students the option of cooperating on homework assignments to the greatest possible extent *(active).* Active learners generally learn best when they interact with others; if they are denied the opportunity to do so they are being deprived of their most effective learning tool.
• Applaud creative solutions, even incorrect ones *(intuitive/global).*
• Give small-group exercises in class *(active/reflective).*
• Talk to student about learning styles, both in advising and in classes. Students are reassured to find their academic difficulties may not all be due to personal inadequacies. Explaining to struggling sensors or active or global learners how they learn most efficiently may be an important step in helping them reshape their learning experiences so that they can be successful *(all types).*

Source: Felder & Silverman (1988, p.680) and Felder & Brent (2006, p. A10).

[2] One example of a learning style is the sensory/visual/active/sequential. Another example is the sensory/verbal/active/sequential.

Felder & Brent (2006) recommended that the teacher does not use all these techniques in every class. The teacher should integrate in his teaching style some of these techniques at a time, keep the ones that work, drop the others, and then try a few more. *"In this way a teaching style that is both effective for students and comfortable for the professor will evolve naturally and relatively painlessly, with a potentially dramatic effect on the quality of learning that subsequently occurs"* (Felder & Silverman, 1988, p.681).

3. The Case Study

3.1 Population of Study

The empirical part of the case study, in an investigation-action context, encompassed students of the curricular unit of Mathematical Analysis I (2008/2009 1st semester), of the plan of studies of the Science Food Engineering of the Superior School of Tourism and Sea Technology (ESTM), of Leiria's Polytechnical Institute. The teacher responsible for the curricular unit in question is, simultaneously, the researcher.

3.2 Description of The Study

Previously, before the beginning of the semester, the teacher/researcher planned the unit of the syllabus. When planning the unit, the teacher/researcher aimed mainly at promoting the students understanding of the contents taught and the involvement of the same students in the learning tasks. The goal was to motivate them and to provoke a positive response and genuine interest in the contents, so as to reach a different motivation to the mere achievement of the unit requisites or of the best quantitative grade possible. Thus, the effort was to encompass all the learning styles defined by Felder & Silverman (1988); establish inter and intra-mathematical connections; develop transversal skills; vary the work modes, the teaching strategies and the assessment tools or elements. In the experiment implementation phase, the following materials were used: a course book designed by the teacher/researcher and given to the students; an assisted teaching platform developed by the Mathematics Teaching Project of the University of Aveiro (PmatE); a battery of tasks of different nature to the exercise: problems, PUTNAM challenge, error finding, thought provoking and conceptual questions.

Some specific teaching strategies were introduced, which resulted of continual study and reflexion of the teacher/ researcher. All these strategies were in fact conceived to promote the effective learning by the students of the contents taught, so as to develop the following skills, according to the Ministry of Education (2001):

- The liking for and the personal confidence to perform intellectual activities that involve mathematical thinking and the concept that the validity of a statement is related to the consistency of the logical reasoning and not to an outside authority;
- The ability to discuss with others and to communicate findings and mathematical ideas through the use of a language, written and oral, non-ambiguous and appropriate to the situation;
- The tendency to use mathematics, in combination with other knowledge, when understanding real situations, as well as discretion regarding the use of mathematical procedures and results;
- Recognise the usefulness of calculus and the development of technical skills in order to solve problems in their educational area, through a mathematical approach;
- Develop critical ability and autonomy.

These were designed with regards to the different learning styles as defined by Felder & Silverman (1988), aiming at encouraging students to adopt a deep approach to learning, specially the contents and subjects that are important to their personal and professional development (Felder & Brent, 2005). Nevertheless, given the nature of the knowledge to be acquired, sometimes it may be necessary to adopt a surface approach (Beattie et al, 1997). Thus, special attention was paid to the factors identified by Biggs (1999) and to the teaching strategies defined by Gibbs (1992), which contribute to and encourage the students to take on a deep approach to learning.

3.3 Strategies Developed

In this section, each of the developed strategies will be briefly presented. They will be associated with the teaching techniques whenever possible, which allows for the inclusion of all learning styles as defined by Felder & Silverman (1988):

- *Coursebook*: The teacher/researcher designed a course book aimed at Higher Education students of Engineering or Science courses, particularly Biology, who are starting the study of Integral Calculus of real functions with one variable. Besides broadening the notions from a theoretical point of view, the course book does not leave out numerical and graphical aspects and emphasizes considerably the applications, looking to show the basis of the numerous notions of Integral Calculus according to the interests of these students, that is, using examples as realistic as possible. The following features of the course book are important:
    - The course book starts with a real problem in the study area of Biology, encouraging the students to consider how the concepts relate to daily situations and to their educational area;
    - The text is clearly laid out, in an organized fashion, with complete notes and carefully planned paging;
    - The course book is easy to understand, in two colours for better visualization of contents;
    - All theorems and definitions are in bold, for emphasis and easy reference. Demonstrations are given for selected theorems so as to enhance the understanding of the students;
    - Observations were included, on the side of many theorems, as well as definitions and examples, allowing further development or describing generalizations;
    - Many examples are presented, as well as their detailed solutions;
    - References to the history of calculus and the mathematicians who developed it;
    - Applications to daily life situations were promoted, thus presenting the link between mathematics and reality, so as to show the students that mathematics is not, using the words of António St. Aubyn (1980), a science *created artificially and with no connexion to reality*;
    - Many different tasks of diverse types were included, giving a wide variety of problems, conceptual questions, thought-provoking questions, finding errors and puzzles. These develop different important skills for using mathematics in real situations; they develop reasoning, discretion and communication; they allow the association of numerous concepts and results showed in the theoretical part; and they appeal to the imagination and creativity, mobilizing skills that are beyond the mere calculus or memorization of definitions and procedures.
- *Using Information Technology*: the teacher/ researcher believes that information technology promotes a more autonomous and self-regulated learning for the students. This stance is shared by several authors, such as (Biggs (2003), Cowan (2000), Dillinger (2001), Felder & Brent (2006), Kanuka & Anderson (1999), Powell (2000), or Tschang (2001). Therefore, this technology was used as a support to teaching the unit Platform of PmatE of the syllabus, where training tasks based on a logic of exercise-solving were made available and also where students carried out some of the components of the unit assessment. For the Blackboard Platform unit, all the materials of the unit were made available; the students could also hand in assignments through a site on the platform designed for that effect, even though they could also do it via email[3]; the teacher also used the Blackboard platform as a way of communicating with the students, either by posting notices on the site of the syllabus unit or by sending emails. The teacher also used the computer with the video-projector to show powerpoint slideshows in the theory lectures, as well as to show graphs and images. Email was also used for bilateral communication between teacher and students.
- *Theory lectures*: traditionally, these classes can be characterized by the "transmission of knowledge" from the teacher to the students. The latter had a passive role, which is the favourite for most students who usually

[3] These options didn't exclude the possibility of handing in an assignment personally or by leaving it in the teacher's pidgeon-hole.

are not active or reflexive. However, one of the goals of this study was precisely to change this fact, aiming at following an active teaching method, centred on the student and establishing dialogue with the students. It should stimulate their imagination, interest, autonomy and discretion, as well as respect their learning pace and style. Thus, it was possible to integrate in these lessons, briefly but systematically, other strategies that allowed the teacher/ researcher to meet the intended goal. The teacher/ researcher intended to follow the scientific method to produce theoretical content, by showing concrete examples of the phenomenon that the theory was meant to be describing (appealing to the *features of a sensitive learner*); afterwards, by developing the theory (appealing to the *features of an intuitive and sequential learner*); by showing how to validate the theory and to deduce its consequences (appealing to the *features of a sequential learner*); and producing applications (appealing to the *features of a sensitive and sequential learner*). Whenever possible, the teacher/ researcher related the contents showed with the ones taught previously and the ones which would be taught further on; and in particular with daily situations and the students' personal experience (appealing to the *features of a global learner*). Frequent breaks were taken during lectures, so that the students could think about the contents shown (appealing to the *features of a reflexive learner*) and also to discuss with their classmates their doubts and questions (appealing to the *features of a verbal learner*). Images were used, as well as schemes and graphs, during and after the verbal presentation of the contents (appealing to the *features of sensitive and visual learners*). Whenever possible, the active participation of students was encouraged, promoting opportunities for students to perform tasks of variable nature, in which they played an active role, so as to do more in class than copy notes (appealing to the *features of an active learner*). A balance was sought between concrete information (facts, data, hypothetical or real situations and their results) (appealing to the *features of a sensitive learner*) and abstract concepts (theory, fundamental principles, mathematical models) (appealing to the *features of an intuitive learner*), and also between the material that emphasizes practice, such as problem-solving (appealing to the *features of sensitive and active learners*) and the material that emphasizes theory and its understanding (appealing to the *features of intuitive and reflexive learners*). Exercises were included, to be solved in small groups of three or four, in class, which were then discussed with the whole class (appealing to the *features of active and reflexive learners*); a few exercises and problems, some simpler, more basic (appealing to the *features of sensitive, active and sequential learners*), others more complex, requiring critical thinking and analytical and synthetic ability (appealing to the *features of intuitive, reflexive and global learners*) to be done as homework. Cooperation among students, in exercise solving tasks, whether at home or in class, was always encouraged (appealing to the *features of all categories*).

- *Seminar-type lessons*: the current practice of this type of lessons was to give the students exercises to solve, but this semester, and since the students had available the training tests for PmatE, which work in a logic of exercise solving, the teacher/ researcher chose to drop the traditional activities in favour of performing tasks of different nature. The change was explained to the students, as well as the benefits of the solving different types of tasks, such as problem-solving, when compared to the mere solving of exercises (Boud & Felleti, 1991). The strategies used were similar to the ones in the lectures. However, it was possible to focus the lessons on the students even more, as the lecture group of students was divided into three seminar groups, thus substantially decreasing the number of students attending each class. This allowed for the class to develop around the questions and doubts of the students, promoting active student participation while solving tasks in small groups and discussing results within the bigger group. The students were able to use the board, to talk to each other and exchange ideas. The teacher/ researcher had the concern to vary the tasks suggested, as had been done for the lectures: ample range of problems, conceptual questions, thought provoking questions, finding the error and puzzles. The main goal was to develop different important skills to use mathematics in concrete situations, developing reasoning, discretion and communication. Students should become able to associate numerous concepts and results learnt in the lectures, to use imagination and creativity and to turn to skills that go beyond mere calculus or memorization of definitions and procedures.

- *Various elements/ tools of assessment*: so that the teaching activities designed and planned by the teacher/ researcher and the learning activities carried out by the students were both guided towards the same goals, the teacher/ researcher sought to line the assessment activities with the learning goals. This is a factor, according to Biggs (2003), which is fundamental for the students to reach the learning goals set by the teacher, because, as advocated by Ramsden (1992), students learn best what they think they will be assessed on. The teacher/ researcher attempted as well to vary the elements/ tools of assessment. Besides the traditional test, the students had to perform other assessment tasks: a subject portfolio; exercises/ problems solved both in class, either individually or in a small group, or for homework.

- *Subject portfolio*: the students were asked to assemble a portfolio with documents on Food Engineering and respective comments. These documents should involve the syllabus contents of the unit "Integral Calculus in IR" and could be gathered by the student from the media, in seminars, on the Internet, in articles, and so on. With the assembly of this portfolio, the students should show the ability to associate the subjects described on the documents chosen and the unit contents. This task is believed to have helped the students build a bridge between the mathematics that are taught in schools and the practical applications of their area of studies.

Although the teacher/ researcher made a considerable effort to plan strategies that would contemplate the different learning styles and promote a deep approach to learning, by encouraging a more active and student-centred learning, in some lessons the students played a more passive role (in lectures, for instance), while in others they performed a more central and active part (in seminars, for instance). Regarding the exploration of the PmatE platform, the students had the opportunity to perform an autonomous role and were able to self-regulate their learning.

4. Conclusion

Preliminary analysis of the data collected through several techniques – surveys, content analysis and participant observation – indicates that instruction designed to address a broad spectrum of learning styles has proven more effective than traditional instruction (almost exclusively magisterial and based on the transmission of knowledge), which focuses on a narrow range of styles.

Although this project is still ongoing, therefore, not yet been concluded, the analysis of collected information, through a questionnaire applied at the end of the semester, allows us to conclude from student feedback that 76% of the students would not modify the approach of the curricular unit, and 24% of the students would have favoured a more traditional approach to the curricular unit, in which the teacher proposes and provides the resolution of more exercises. Most students consider that they became actively involved in the learning process. The results analysis from the data obtained from the assessment tests and work produced by the students allowed the conclusion that, compared to students from previous years, who were subjected to a more traditional teaching method, these students improved their performance and developed a greater critical ability and autonomy.

Poor grades in mathematics seem to be widely accepted as a fact of our educational system, and what is more disappointing is that such a fact is confirmed by international statistics reports. It is important to face this reality and take a proactive approach towards this problem, to reduce its effect.

5. References

Almeida, P. (2007). Questões dos alunos e estilos de aprendizagem –um estudo com um público de ciências no ensino universitário. Aveiro: Universidade de Aveiro. (PhD thesis)

Biggs, J. (1985). The role of metalearning in study process. *British Journal of Educational Psychology*, 55, pp. 185-212.

Biggs, J. (1999). *Teaching for Quality Learning at University*. Buckingham: Open University Press.

Costa, A., Santos, S. & Simão, J. (2003). *Ensino Superior: uma visão para a próxima década*. Lisboa: Publicações Gradiva.

Cowan, J. (2002). *Como ser um professor universitário inovador – reflexão na acção*. Porto Alegre: Artmed.

Edmunds, R. & Richardson, J. (2009). Conceptions of Learning, approaches to studyinga d personal development in UK higher education. In *British Journal of Educational Psychology*, 79 (2), 295-309.

Entwistle, N. (1981). Styles of learning and teaching. New York: Wiley.

Entwistle, N., McCune, V. & Walker, P. (2000). Conceptions, styles and approaches within higher education: analytic abstractions and everyday experience. In: R. J. Sternberg & L. F. Zhang, *Perspectives on Cognitive, learning and thinking styles. Mahwah*, N J: Erlbaum.

Felder, R. & Brent, R. (2005). Understanding Student Differences. In *Journal of Engineering Education*, 94 (1), 57-72.

Felder, R. & Brent, R. (2006). *Effective Teaching: A Workshop*. Aveiro: University of Aveiro.

Felder, R. & Silverman, L. (1988). Learning and Teaching Styles in Engineering Education. In *Engineering Education*, Vol. 78, No. 7, 674–681. Online at *http://www.ncsu.edu/felder-public/Papers/LS-1988.pdf*.

Felder, R. & Solomon, B. (s.d.). Index of Learning Styles. Online at *http://www.ncsu.edu/felder-public/ILSpage.html*.

Felder, R. & Spurlin, J. (2005). Applications, Reliability, and Validity of the Index of Learning Styles. *International Journal of Engineering Education*, vol. 21, nº1, 103-112.

Gibbs, G. (1992). *Improving the Quality of Student Learning*. Bristol: Technical and Education Services.

Jung, C. (1921). *Psychological types*. Princeton: Princeton University Press.

Keefe, J. (1979). Learning Style: an overview. In J. W. Keefe (Ed.), *Student learning styles. Diagnosing and prescribing programs*, 1-17. Reston, V A: National Association of Secondary School Principals.

Kolb, D. (1984). *Experiential Learning: Experience as the source of learning and development*. Englewood Cliffs: Prentice Hall.

Kolb, A. & Kolb, D. (2003). *Learning Styles and Learning Space: Enhancing Experiential Learning in Higher Education*. Online at http://www.learningfromexperience.com/Research_Library.htm.

Kolb, A. & Kolb, D. (2005). Experiential learning theory bibliography. Experience Based Learning Systems, Inc. Online at http://www.learningfromexperience.com.

Kolb, A. & Kolb, D. (2006). Learning styles and learning spaces: a review of multidisciplinary application of experiential learning theory in higher education. In Sims, R., & Sims, S. (Eds). *Learning styles and learning: A key to meeting the accountability demands in education*. NY: Nova Publishers.

Light, G. & Cox, R. (2001). *Learning and teaching in higher education – the reflective professional*. Thousand Oaks: Sage Publications.

Morin, E. (2002). *Os Sete saberes para a Educação do Futuro*. Lisboa: Instituto Piaget.

Niss, M. (2003). Mathematical competencies and the learning of mathematics: the Danish KOM project. In A. Gagatsis and S. Papastavridis (eds), *3rd Mediterranean conference on mathematical education: Mathematics in the modern world, mathematics and didactics, mathematics and life, mathematics and society*, 115-124. Athens : Cyprus Mathematical Society.

Ramsden, P. (1992). *Learning to Teach in Higher Education*. London: Routledge.

Richardson, J. (2005). Students' Approaches to Learning and Teachers' Approaches to Teaching in Higher Education. *Educational Psychology*, 25 (6), 673-680.

Sebastião e Silva, J. (1975). *Guia para a utilização do compêndio de Matemática*. 1º volume. Lisboa: Edição GEP do Ministério da Educação e Investigação Científica.

Teixeira-Dias, J., Pedrosa de Jesus, H., Neri de Souza, F. & Watts, M. (2005). Teaching for quality learning in chemistry. *International Journal of Science Education*, 27(9), 1123-1137.

Zhang, L. (2005). Does teaching for a balanced use of thinking styles enhance students' achievement? *Personality and Individual Differences*, 38, 1135-1147.