A^3 Learning System: Advanced Active and Autonomous Learning System

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***Abstract*—This paper proposes the Advanced-Active-Autonomous (A^3) Learning System, which is an educational system based on the use of information and communication technology. The A^3 Learning System is a combination of Active Learning (AL), Project/Problem-Based Learning (PBL) and Mastery Learning (ML). We report some uses of the A^3 system and implemented AL and ML in foundational learning in the software/hardware information fields. Additionally, we implemented PBL in software design. We implemented two methods; one involves individual students and the other involves a group. Furthermore, to evaluate the benefits of the A^3 Learning System, the Progress Report on Generic Skill (PROG) test was carried out; the results of the test are discussed here.**

***Index Terms*—A^3 learning system, computer education, active learning, project/problem-based learning, mastery learning**

I. INTRODUCTION

Society is in need of human resources who possess skills relevant to the 21st century and who can learn and operate higher educational facilities. Students should have advanced knowledge and ability to solve social issues, both regionally and globally, in an autonomous, collaborative and constructive way. Therefore, a new education system, which radically alters the traditional education system, is desired. This education system is designed to increase the ability of each student to his/her full potential and to educate the human resources who can then respond to social needs. In particular, learning systems that implement Active Learning (AL) are attracting attention worldwide [1][2][3][4], and the benefits of such systems are highly regarded [5][6]. However, the construction of effective learning systems, including AL, has been lacking and there is a particular need for systematic education systems, including Project/Problem-Based Learning (PBL) and Mastery Learning (ML), in the field of engineering education.

In response to this issue, we have been developing systems to encourage autonomous learning using information and communication technology (ICT) devices, such as computers and tablet. We have constructed a framework for guaranteeing the quality of education while carrying out AL trial lessons, which actively involve collaborate learning using computers and tablets. Using this approach, multiple instances of AL and PBL have been introduced while carrying out traditional knowledge-transfer based lecture-centric courses.

In this paper, based on the above approach, we have proposed an Advanced-Active-Autonomous (A^3) Learning System, which is a new educational system based on the use of ICT devices. A^3 Learning Systems comprise AL, PBL [7][8][9] and ML [10][11][12][13][14]. This is a departure from the traditional teaching style to the AL learning style. Traditional teaching fits a fixed quantity of knowledge into a specific time frame. The A^3 system encourages students to learn by themselves to meet their individual goals. Furthermore, the PROG test, which has some improvable elements [15], was carried out to evaluate the educational benefits of the A^3 Learning System. In addition, this method is discussed as a method of evaluating 'literacy', leading to the practical resolution of problems and 'competency', which is the skill used to forge good relationships with the surrounding environment.

This paper is organised as follows. In the Introduction section, we described an overview of the background to this study. In section two, we discuss the A^3 Learning System and class design. In section three, we examine the A^3 Learning System courses in practice while section four provides an evaluation of the system. Finally, in section five, we provide both a summary of the paper and discuss issues moving forward.

II. WHAT IS THE A^3 LEARNING SYSTEM?

A. Overview of the A^3 Learning System

The A^3 system uses the student's motivation and personal growth, as shown in Fig. 1. The students look at the problem, discuss it among themselves and autonomously develop a method to solve it. We support their education system and environments. The A^3 Learning System comprises AL, PBL and ML and uses ICT devices such as computers and tablet terminals. This learning structure not only extends the abilities of each student but encourages them to participate in active and autonomous learning, which in turn reduces the load of course preparation and course management on the teaching staff.

For students to equip themselves with 'reliable knowledge', 'thinking faculties/inventiveness', 'practical skills' and 'generic capabilities' such as foundational competencies for teachers to produce students that can respond to a diverse array of carriers, an educational system that can respond flexibly to the abilities and objectives of the individual students is required. That is, for students with varied objectives for both content and amount of information, the A^3 Learning System has moved away from the traditional style in which a fixed of knowledge is crammed in, to a progressive learning system in which the amount of active and autonomous learning changes to the objective achievement level of the individual student. Furthermore, the A^3 Learning System

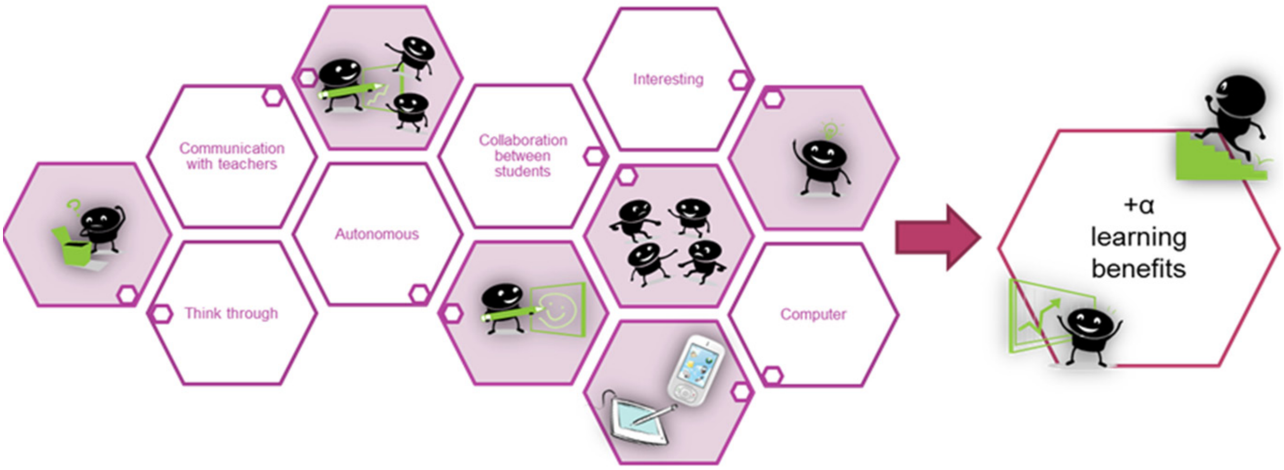

Figure 1. Magnetization as a function of applied field. Note how the caption is centered in the column

includes an evaluation of 'literacy' leading to the practical resolution of problems and 'competency', which is a skill required for constructing good relationships with the surrounding environment. In the United States and Europe, the following methods are used to evaluate AL's usefulness in measuring ability that differs from academic results: Collegiate Assessment of Academic Proficiency (CAAP) and the Collegiate Learning Assessment (CLA). However, these have both cost and time drawbacks. A student questionnaire is sometimes used to measure the effect of the introduction of AL. However, objectivity is weak and does not guarantee the precision of CAAP and CLA. Therefore, with the A^3 Learning System, a PROG test was used because it does not rely on subjective evaluation. By evaluating the growth of each student, both literacy and competency can be evaluated.

B. Types of A^3 Learning System

The A^3 Learning System comprises three systems: AL courses, PBL and Mastery Learning. The specific learning forms are as follows.

AL: Lessons include activities in which students 'learn by themselves or with their fellow students'. This type of learning cultivates their 'learning skills' while obtaining a deep level of knowledge. A large amount of group work (pair work) and discussion is included. ICT devices and electronic materials are positively used, and flip teaching is also considered to be effective.

PBL: This cultivates the thinking faculties (skills to resolve issues, creativity, and so on) and practical skills (actual manufacturing and problem resolution using knowledge and technology) as well as foundational skills as a team-member, which are necessary to carry out the project. By setting themes in a wide variety of fields, knowledge from each field is merged and deepened. By setting themes linked to society, it is possible to have an image of philanthropy as a member of a society.

ML: This is a style of individual learning in which each unit is learned at one's own pace. Once that unit is fully mastered, there is a transition to the next unit. Lessons comprise individual guidance and face-to-face lessons for support. As there are differences in the speed of understanding for each student, lessons that proceed at the pace of the instructor cannot, in principle, avoid leaving behind some students with incomplete knowledge. ML is a lesson style that resolves this issue.

The concept of the A^3 Learning System is shown in Figure 1. As shown in this figure, through the three approaches of AL, PBL and ML, learning is achieved through students' active and autonomous learning. Additionally, communication among students and between student and instructor, and the use of computers provides learning benefits to traditional learning content.

III. THE A^3 LEARNING SYSTEM IN PRACTICE

A. Overview of the A^3 Learning System in Practice

In the proposed A^3 Learning System, the Computing Education Field has also adopted a curriculum design and practice specialising in software education. In concrete terms, experiments on foundational learning in the field of software/hardware information, through AL and PBL, from software design to system implementation, were conducted through two methods involving individual students as well as groups.

B. AL Practical for Software-Related Subjects

The AL A^3 Learning System was put into practice for the software-related subject, Knowledge Engineering course. The aim of this course is to provide an introductory education on artificial intelligence and knowledge engineering, and comprises an overview of artificial intelligence, search methods, expert systems, production systems, the latest trends, etc.

In this subject, as shown in Figure 2, the group and the individual learning-type AL have both been mutually adopted. More specifically, introductory learning that adopted group learning-type AL was conducted for part of the previous important lecture-based courses that students struggled with or found difficult to understand.

During the group learning-type AL, there was positive discussion and inter-teaching between students, which fostered understanding among them. In particular, when learning the 'rule set' in production systems, group learning-type AL was carried out in which specialized knowledge was summarized as a 'rule set'. The target themes were not specified by the instructor but instead determined by the discussions among the students in each group, thereby stimulating autonomous learning through practical learning of the themes in which the students themselves were interested. There were a wide variety of themes, from animation on TV to cooking recipes, and this activity generated excitement among all of the groups. The rule sets completed by each group were firmly in place, and it was determined that the content to be learned was sufficiently understood. Furthermore, we applied the individualized learning type AL to the recent trends related to IT. When students are interested in a theme they are likely to research in more depth; therefore students are likely to give a wide variety of answers. For example, in the case of AL based on the theme 'learning', individual learning was promoted on a topic that individuals found interesting. Additionally, these learning methods, from the most recent research trends to learning via SNS and games, allow for a wider range of content to be covered than what was prepared by the instructor alone. In this way, learning can be broadened and deepened through the use of individual learning-type AL.

Through the presentation and lively discussion of the surveyed content, it was possible to come into contact with a diverse array of answers and understanding in a broader, deeper way. In this way, students were able to reach conclusions that reflected each other's opinions. Additionally, teachers do not nominate a presenter until just before the presentation; this caused all the students to prepare their own presentations and, in the process, gain a deeper understanding of the subject.

Furthermore, as a trial for ML, we confirmed how much the students had learned through short tests on the important areas of the course. In particular, a short test was conducted on the key points after each group learning-type AL covered important content. For all of the content that was covered during group learning-type AL, sufficient learning was determined by students achieving an average score of 8–9 points out of 10 on the tests. It was confirmed in this way that, by introducing the elements of AL and ML into the previous lecture-centric courses, the autonomous learning of students could be encouraged. In addition, it was also confirmed that the ML method is effective in confirming the level of understanding by using short tests for students on important areas, and so on.

C. *AL practical of Hardware-related subjects*

The A^3 Learning System was also used during a digital circuit course, a hardware-related subject. The aim of this course is to provide the technical knowledge of several digital circuits. In this learning system, which we have being using until now, experiments, training, lectures and exercises are linked in an organic and systematic way; we term this system 'spiral education'. The curriculum is based on these concepts. We designed the AL course to use the merits of spiral education to achieve these subjects' aims.

For this subject, multiple units related to digital circuits, such as logical gates, counters, registers, the digital-analog (DA) converter and the analog-digital (AD) converter, have been prepared. In courses up until now, the structure has been such that a number of practical sessions are carried out together after multiple lectures have been successively completed. With this design, there are concerns that the quality of education will suffer because of the gap of a week or more between the lecture and the practical sessions. Therefore, in the digital circuit course in which we aim to practice the A^3 Learning System, we planned lessons that proceed in a spiral shape with reviews, lectures, training and exercises taking place relative to one another in one lesson within one unit and introduced these into the course as necessary.

Number of Lesson	Lesson Content	Check
1 Lesson	Lecture	Confirmation Short Test
4 Lessons	Group learning-type AL	
4 Lessons	Individual learning-type AL	
2 Lessons	Lecture	
2 Lessons	Group learning-type AL	Confirmation Short Test
2 Lessons	Individual learning-type AL	

Figure 2. Example of the course design with AL in the knowledge engineering Course

Number of Lesson	Lesson Content
2 Lessons	Logical gate
4 Lessons	Counter
3 Lessons	Resister
3 Lessons	DA Converter
3 Lessons	AD Converter

(a One year)

Time	Content	Detail
10 min	Lecture	Confirmation of the Knowledge
40min	Lecture	Description of the new contents
		Individual work (AL)
		Group work 1 (AL)
		Group work 2 (AL)
50min	Pair Works	Training and Exercise
10min	Lecture	Conclusion

(b) A single lesson

Figure 3. Example of the course design with AL in the digital circuits course

3 (a) and (b) show example of the lesson contents of the digital circuit course and course design with AL in a single lesson, respectively. The lessons progressed within a single unit and adopted the group learning-type AL which used the inter-teaching approach to avoid the 'one-way' type of lessons in which students' awareness of the objectives tended to decrease. One lesson comprises a review of the knowledge acquired up to that point, and lectures, training and exercises to learn new knowledge, as well as a summary. During the lectures, time was allotted for individuals to think (individual work), as well as time for pairs or groups to learn from one another (group work). When necessary, this process took place multiple times within the lecture. In addition to improving students' cognitive abilities and establishing knowledge, this process also aimed to increase the communication ability of the

students. The intention of the aforementioned framework was not only to make it possible to listen to the opinions and thoughts of other students within the group, thus enriching the thoughts of the students themselves, but also to further engrain knowledge in a deeper way through the use of inter-teaching between the students.

Reviews at an early stage are effective in increasing understanding and engraining course content. Therefore, the content of the practical elements and exercise carried out in the second half of the lesson was content-linked to the lecture carried out to confirm the level of understanding. Furthermore, elements of ML were introduced in the practical elements and exercise. Students can practice and work on the exercises at their own pace.

In addition, the contents of the lecture can be extremely effective in aiding understanding as they involved practical exercise. Furthermore, as practical training involves approaching problems by forming pairs within members of the group work, the knowledge required for the practical training is shared between the pair. This also ensures a healthy level of communication between students within the lecture time. In this way, the framework used inter-teaching within the group during lecture time for practical training as well. For practical training, it is often the case that inter-teaching between students occurred without any encouragement from the instructor, which suggests that both AL and ML were functioning.

This course design also aimed to improve student activity by intentionally increasing this inter-teaching between students. When carrying out trial lessons with this lesson structure, communication among students progressed very smoothly and the instructor felt that the lessons became livelier than before. During the practical training, issues were being tackled with more vigour than before. The activity level of students seemed to increase, and the level of understanding and entrenchment of specialized content also seemed to improve. By introducing AL into the course, not only was the specialized knowledge entrenched but improvements were also promoted in the autonomous learning and communication abilities of the students.

D. Group-type PBL practical of Software design development

A group-type PBL A^3 Learning System was put into practice in the software design development course. The objective of this subject was to learn the object-oriented development method, and the course structure comprised the two parts of learning: the object-oriented analytical design method using UML and the practice of the software development process. We introduced PBL into the latter. A theme of PBL is practical application development. In this PBL, as shown in Figure 4, the theme was an Android application; this was developed in the three phases of specification research (three times), implementation (four times) and presentation (one time). Each group consisted of 4–5 members and they were chosen based on aptitude in software development and communication ability.

The flow of the practical training is as shown below. At the start of the training, a sample Android application was proposed by the instructor. Development of the application entailed adding functionality to this proposal. First, during the specification research phase, a sample is analyzed

Number of Lesson	Lesson Content	Check
4 Lessons	Learning of UML	
3 Lessons	Learning of Android Application	
3 Lessons	System design	Specification report
4 Lessons	Implementation	
1 Lesson	Presentation	Final report

Figure 4. Magnetization as a function of applied field. Note how the caption is centered in the column

using the UML method learned from the first half and specifications, such as class diagrams or sequence diagrams, are created. The functions to be added to this are discussed and, in addition to creating the external specification, the specification is revised using UML. Next, based on the revised specification, the program is created during the implementation phase. Although there are differences in programming ability among the students, all students are encouraged to participate in the program creation as much as possible. Finally, the program is completed and the results of the development are presented.

Through executing PBL, we learned to check students' daily work reports and the group reports. An increase in academic ability was seen as a result of improvements in communication and inter-teaching within the group. Generally, an issue in software-related subjects is that there tends to be a clear difference in ability between students compared with other subjects, but it seems that PBL deepened the understanding of many students. By selecting PBL themes that would attract the attention of students, it is possible to motivate many of the students. Furthermore, we heard from those reporting that as there were disparities in development skills within the group; however, contributions were made to the project through the division of roles.

E. Individual-type PBL practical of CG Application Development

In the Computer Graphics (CG) course, which is a software application practical subject, the A^3 Learning System was put into practice with an individual-type PBL. With the objective of understanding CG programming and the theory of CG, this course consists of lectures on the theory of CG and freely-created CG projects by each student.

For this subject, an individual-type PBL was adopted to allow each student to experience the full software development process. In concrete terms, the software to be developed is determined by the students themselves, and all of the processes from creating software requirement specifications to the design are implemented and tested by the students. The CG projects are completed at the student's own pace. Practical training is based on software development as undertaken by a company, rather than simply as a subject. Therefore students submit reports at every step. As shown in Figure 5, the submission of this report as a function of ML was important in confirming the progress for each development process and the level of understanding.

Number of Lesson	Lesson Content	Check
4 Lessons	Lecture and Practice	
1 Lesson	System design	Specification report and Schedule chart
7 Lessons	Implementation	
		Progress report
1 Lesson	System test	
2 Lessons	Presentation and Demo	Final report

Figure 5. Example of course design with PBL in the CG application development course

The production of the CG project promotes student creativity because the work themes are initiated by the students. Furthermore, by completing the design and development themselves, every student can benefit by experiencing the entire development process. For software development, it is necessary to understand the whole process, and by the PBL being carried out by the student themselves rather than groups, all the students can experience the entire process. Additionally, with the introduction of ML elements, training is possible at the pace of each individual student. In this way, it is possible to escape a traditional type of course.

Both types of software development PBL, including the group-type PBL and the individual-type PBL, make the student aware of the development process within a company and allow them to experience the whole process from the requirements analysis/design to implementation and delivery. This has the benefit of emphasizing the importance of document creation and deadlines, which contributes to the nurturing of the foundational skills necessary for them to become members of society.

IV. EVALUATION OF A^3 LEARNING SYSTEM

A. Enhancing and Evaluating Foundational Skills

To empirically evaluate students' foundational skills established by practising the A^3 Learning System, PROG, a measurement of generic skills, was applied. PROG considered the data of young leaders in the real society as a model of a teacher so that the evaluation standard is possibly identical to the level widely acceptable to the society. In addition, it has been implemented by more than 110,000 university students. This means that it is possible to assess students' 'literacy', an ability to practically solve problems, and 'competency' for establishing a healthy relationship with the environments surrounding them. Despite its usefulness, however, it is not sufficient to conduct PROG only once to identify the characteristics of test participants. It is essential to continually implement PROGs to all university students to see growth in their abilities from enrolment to graduation. For this, PROG is used once a year, consecutively. Although we must wait for a few years to analyse this longitudinal data, the PROGs pre and post the implementation of the A^3 Learning System provided information for its learning effect.

B. Analysis of the Students' Potentiality

Table 1 shows the means of literacy and competency scores before applying the A^3 Learning System. Comparing with all the university students, the student group in this campus showed the higher scores, particularly in literacy. The highest value in the components of literacy compared to other students was 'inventive skills: an ability to consider, choose and practice a solution under a variety of conditions and restrictions.' Concerning competency, the 19-year-old student group showed the highest values in 'intimacy' in the category of interpersonal skills and 'emotion control skills' in the category of self-controlling ability. 'Project planning skills' in the category of basic skills for task management, on the other hand, was lower than other university students in Natural Sciences, especially the values of 'objective setting', 'scenario structuring' and 'project assessment.' These characteristics show the inclination that students in this campus are weak in 'planning.'

C. Analysis of PROG Results Before and After the A^3Learning System Application

Figure 6 shows the PROG results from 2014 and 2015. By comparing the results of the first year students in the Year 2014 ('14_1st) with the second year in the Year 2015 ('15_2nd), it is noticeable how their scores have changed over time. The A^3 Learning System has been implemented since 2015. The test results of 2014 reflect the previous education system whereas the results from 2015 partly reflect the impact of the A^3 Learning System. In other words, the development of the average score shown in Figure 6 by arrows identifies the impact of this learning system on students' achievement. The data of '15_5th, however, lacks a specific subject in the process of implementation so that it cannot be used as the data for analysis.

Test results for 2014 show that the previous education system at this campus focuses on the acquisition of literacy. The literacy scores have increased over time whereas the competency score decreased from the first year to the third year and increased in the final year. This could be because students have many opportunities for individual study and task management at the first half of their life in our college life but less time to develop competency. In their final year, however, the competency scores increase because students find various opportunities to develop teamwork skills and relationship management skills such as internships, job-hunting and final research projects.

Concerning the impact of the A^3 Learning System implemented in 2015 in Figure 6, the drastic development of competency can be observed. Furthermore, the competency score of the first year students in 2015 ('15_1st) were already higher than the level 3, proving that the proposed education system in this paper has a significant effect even on new students.

Literacy scores of the first, second and third year students in 2014 reached the same level as the fourth year students in 2014, showing the positive impact of the A^3 Learning System on students' literacy.

Despite these results, it is impossible to ignore the students' differences in potentialities. In other words, the existing data used for this study are not sufficient for in-depth analysis. Further data collection and analysis are thus required.

TABLE I.
PROG TEST RESULTS (GENERAL)

(The respective abilities are shown as average values evaluated in seven stages)

	19 year olds	20 year olds	All university students
General literacy	5.6	5.6	3.8
General competency	3.8	3.3	3.2

TABLE II.
COMPETENCY – EXCERPTS FROM LARGE/MEDIUM-SIZED CLASSIFICATIONS

(University students: Engineering/Science & Technology/Information Engineering majors)

		19 year olds	20 year olds	University 3rd year	University 4th year
Interpersonal foundational skills average		4.0	3.4	3.4	3.5
Personal foundational skills average		3.9	3.5	3.5	3.7
Inter-subject foundational skills average		3.8	3.7	3.9	4.2
Interpersonal	***Affinity***	4.4	3.2	3.5	3.6
Personal	***Emotional control***	4.0	3.5	3.4	3.7
Inter-subject	***Planning skills***	3.4	3.3	3.6	3.9

V. CONCLUSION

This paper aimed to explore a new type of education that raised students' awareness about skills and abilities required by the contemporary society and to critically understand their current competence, whose goal was to nurture students who have maximized their potential abilities to satisfy the social needs. For this, the existing education system was drastically modified by the proposed Advanced-Active-Autonomous (A^3) Learning System and the use of ICT devices.

Although they were preliminary, the PROG results proved that the proposed education system effectively facilitated students' development of competency, which had been difficult to promote for new students under the previous system. The levels reached almost the same as those of final year students.

It is crucial to thoroughly investigate the relations among literacy, competency and the A^3 Learning System, and we plan to continue data collection for further research. Detailed analysis, including which pedagogical elements in the proposed system affect students' skills and abilities for each domain, should be also carried out.

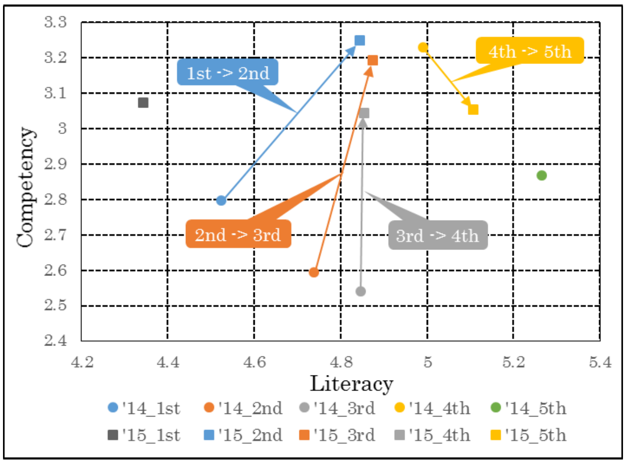

Figure 6. Average values of the total scores of literacy and competency of the students at our campus

REFERENCES

[1] H. Niemi, 'Active learning—a cultural change needed in teacher education and schools,' Teaching and Teacher Education, vol. 18, pp. 763–780, 2002. http://dx.doi.org/10.1016/S0742-051X(02)00042-2

[2] M.W. Keyser, 'Active learning and cooperative learning: understanding the difference and using both styles effectively,' Research Strategies, Vol.17, pp.35–44, 2000. http://dx.doi.org/10.1016/S0734-3310(00)00022-7

[3] N.F. Hassan, S. Puteh, and R. Buhari, 'Student understanding through the application of technology enabled Active Learning in practical training,' Procedia - Social and Behavioral Sciences, Vol. 204, pp. 318–325, 2015. http://dx.doi.org/10.1016/j.sbspro.2015.08.158

[4] N.M. Mingazova, 'Modification of the Active Learning methods in environmental education in Russian universities,' Procedia - Social and Behavioral Sciences, Vol. 131, pp. 85–89, 2014. http://dx.doi.org/10.1016/j.sbspro.2014.04.083

[5] S. Freeman, S.L. Eddya, M. McDonougha, M.K. Smithb, N. Okoroafora, H. Jordta, and M.P. Wenderotha, 'Active learning increases student performance in science, engineering, and mathematics,' PNAS, Vol.111, no.23, pp.8410—8415, 2014. http://dx.doi.org/10.1073/pnas.1319030111

[6] S.L. Eddy, M. Converse, and M.P. Wenderoth, 'PORTAAL: A Classroom Observation Tool Assessing Evidence-Based Teaching Practices for Active Learning in Large Science, Technology, Engineering, and Mathematics Classes,' CBE-Life Sciences Education, Vol. 14, pp.1–16, 2015. http://dx.doi.org/10.1187/cbe.14-06-0095

[7] Jacobo Rodrı´guez, Ana Lavero´n-Simavilla, Juan M. del Cura, Jose´ M. Ezquerro, Victoria Lapuerta, and Marta Cordero-Gracia, 'Project Based Learning experiences in the space engineering education at Technical University of Madrid,' Advances in Space Research, Vol. 56, pp. 1319–1330, 2015. http://dx.doi.org/10.1016/j.asr.2015.07.003

[8] L. Zhiyu, 'Study on the cultivation of college students' science and technology innovative ability in electrotechnics teaching based on PBL Mode,' IERI Procedia, Vol. 2, pp. 287–292, 2012. http://dx.doi.org/10.1016/j.ieri.2012.06.090

[9] Sandra Raquel Gonçalves Fernandes, 'Preparing graduates for professional practice: findings from a case study of Project-based Learning (PBL),' Procedia - Social and Behavioral Sciences, Vol. 139, pp. 219–226, 2014. http://dx.doi.org/10.1016/j.sbspro.2014.08.064

[10] K. Kularbphettonga, P. Kedsiributa, and P. Roonrakwit, ‘Developing an adaptive Web-Based Intelligent Tutoring System using Mastery Learning technique,’ Procedia - Social and Behavioral Sciences, Vol. 191, pp. 686–691, 2015. http://dx.doi.org/10.1016/j.sbspro.2015.04.619

[11] M.E. Damavandi, and Z.S. Kashani, ‘Effect of mastery learning method on performance and attitude of the weak students in chemistry,’ Procedia Social and Behavioral Sciences, Vol. 5, pp. 1574–1579, 2010. http://dx.doi.org/10.1016/j.sbspro.2010.07.327

[12] N. Shafie, T.N.T. Shahdan, and M.S. Liew, ‘Mastery Learning Assessment Model (MLAM) in teaching and learning mathematics,’ Procedia Social and Behavioral Sciences, Vol. 8, pp. 294–298, 2010. http://dx.doi.org/10.1016/j.sbspro.2010.12.040

[13] G. Gladding, B. Gutmann, N. Schroeder, and T. Stelzer, ‘Clinical study of student learning using mastery style versus immediate feedback online activities,’ PHYSICAL REVIEW SPECIAL TOPICS - PHYSICS EDUCATION RESEARCH, Vol. 11, 010114, 2015. http://dx.doi.org/10.1103/physrevstper.11.010114

[14] C.L.C. Kulik, J.A. Kulik, and R.L. Bangert-Drowns, ‘Effectiveness of Mastery Learning Programs: A Meta-Analysis,’ REVIEW OF EDUCA’TIONAL RESEARCH Summer, Vol. 60 no.2 265–299, 1990.

[15] H. Ito, ‘Assessing an Assessment Tool of Higher Education: Progress Report on Generic Skills (PROG) in Japan,’ International Journal of Evaluation and Research in Education (IJERE), Vol.3, No.1, pp. 1–10, 2014.

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