

# Case Study Evaluation of Adaptive Learning Incorporation to Educational Delivery Method

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**Abstract—** Adaptive learning is an outcome of new technologies integration into the educational process, following the transformation of the educational content into diverse forms. The implementation of this educational methodology in practice (case study) allowed for the evaluation of its effectiveness towards the educational goals as well as the participants. Samples are collected through educational process evaluation tests and presented statistically. Analysis of these samples reflects the validity of the adaptive learning value in educational process.

**Keywords—** Statistical analysis, closed form questionnaires, learning path, adaptive learning, adult training

## I. INTRODUCTION

Rapidly changing technological advances as well as modern lifestyle impose challenges to the educational and training procedure [1,2]. Learners tend to prefer the Internet as knowledge source, degrading the trust towards the structured learning process [3]. This is enhanced by societal requirements, being diverse and intense, suppressing the allowance for personal devotion, required for learning process [4]. Foundations of knowledge are questioned against modern theories [5], as at the same time productivity depends increasingly on expertise [6]. The sound and enduring learning background accumulation is crucial to attract attention and maintain loyalty of learners into the educational system [7]. At the same time, modernization of the educational system requires more than utilities and plugins, rather an integrated, user experience educational interface [8, 9]. In this direction, an initiative to deliver a module with the integration of new technologies was adopted several years ago. Participation statistics are utilized in this study to prove the value of adaptive learning into the learning process.

Knowledge is a stepwise process of several stages, consisting of tree-like structures of terms and definitions. The knowledge path, meaning the way the tree is passed through, is guided by the educational service provider and is expected to be followed by the educational participants. Traditional educational methodologies adopt formalized knowledge paths, discouraging leeway and alternative paths. This is a

major drawback as the pluralism in available knowledge paths enhances the inclusion of diverse attitudes and result to the strengthened engagement of the participants. Personalization of learning process involves the availability of redundant knowledge paths, addressing characteristics of the participants. The development of these redundant knowledge paths adopting alternative educational methods, result to different flavors in approaching the educational targets. Equal access and inclusion may benefit from this flexibility without relaxing academic integrity and societal requirements. In our case the tool 'learning path' available in platform was utilized in order to integrate diverse forms of educational material into a thematically integrated learner experience. The initiative covered many modules, incorporating innovative educational content delivery methods, but this study will cover only one module.

Even though traversing a path is a time and space straightforward process, learning paths should be time indifferent, and passed through as a unidirectional graph. Due to the time separation of learning process, the participant should be able to repeat past parts of the path, in order to refresh memory or attitude, before stepping forward. This space separation of the educational path into branches allows chunks of knowledge to be fed into the conceptual sphere of the participant in a modular way, allowing for more flexible educational process application and more elaborate scope accomplishment. In the under investigation case, this feature of 'learning path' was realized with multiple independent thematical subsections, as shown in Figure 1. aligned to the syllabus of the module, but capable to be run randomly. Each thematical chunk ended up to a self-assessment test, allowing the participants to review the dimensioning of their learning sphere and re-engage to the process.

ΨΗΦΙΑΚΑ ΣΥΣΤΗΜΑΤΑ - ΔΙΚΤΥΑ ΥΠΟΛΟΓΙΣΤΩΝ -  
Γραμμές μάθησης

Γραμμές μάθησης
<b>1.1 Λογικές Μεταβλητές</b> Γενική εισαγωγή
<b>1.1 Αλγεβρά ΒΟΟΛΕ</b> Ενότητες βιβλίου 1.4.1, 1.4.2, 1.4.7 έως και 1.4.10 και όσες ασκήσεις
<b>1.2 Δυναμικοί Κώδικες</b> Ενότητες βιβλίου 1.4.3 και όσες ασκήσεις εμπίπτουν στην θεμα
<b>1.3 Λογικές Πύλες</b> Ενότητες βιβλίου 1.4.3 έως και 1.4.6 και όσες ασκήσεις εμπίπτουν
<b>1.5 Αρχιτεκτονική Συστήματος</b>

Figure 1 Learning path page print out.

Effective educational process is based on results achieved, that are an outcome of evaluation procedures. Nevertheless, the result reflects the overall procedure, lacking track of the process progress, and as such dynamic adaptation. The latter, as an expert could do, would thrush the performance of the learner, leveraging potential weaknesses or fallbacks that are encountered. Application of sensors through the whole educational process can automate the progress monitoring, intensify the depth and breadth of evaluation and provide a near real time feedback capability. The convolution of sensors' data form a lake of perception, allowing for corrective steps adoption early on the acknowledgement trajectory. Moreover, due to formalization of evaluation methods, personalized feedback may become available without tremendous involvement of resources. In the next sections, an attempt to develop metrics upon statistics provided by the educational platform is presented, focusing on the valorization of adaptive learning.

## II. ADAPTIVE LEARNING RATIONAL

Technological evolution has enabled the so called "new technologies" to participate into educational process. Their participation varies according to stage and integration, discriminated into technology-led [10] and technology-assisted [11] or between naïve [12, 13] and aware [14]. The best way for adopting them in the learning process is to define how they can drive to positive outcomes through five general directions:

- **Automation:** Scope of this direction is to achieve economies of scale, simplify/unify procedures, and support learning autonomy. Administration may leverage cost through resources reusage while acquiring robust and timely services' delivery. Educators may simplify straightforward tasks such as grading, digital asset categorization or timetable scheduling, while at the same time enjoy qualitative time with the learners, motivating them to outperform. Learners acquire close look at their activities, leading to rolling feedback, enjoying a transparent interaction environment.

- **Integration:** Scope of this direction is to accomplish physical and logical integration of the new technologies into the educational process. The discrimination of knowledge trees into artefacts and linking them together into a knowledge path allows for the monitoring and metering of the educational process. The unified, cultural and societal sensing environment allows the learner to experience a complete, realistic approach to knowledge acquisition. Evaluation of educational process' progress utilizes transparent procedures while learners' performance is based on a more personalized approach. Incorporation of technology follows educational needs and objectives, assisting or leading learning process.

- **Acclimation:** Scope of this direction is to achieve the onboarding of education process's participants onto the evolution train, making them aware of their potential. Innovative products come to complement the educational process, allowing for outperformance of solicited issues alongside. Bringing educational service providers into contact with them shall reinforce their acknowledgement of new tools and methods, reshaping their comprehension of the educational service delivery. Learners may enjoy improved educational services access, forming a personalized, tailor made to their characteristics learning process. Administration may account for all the above, forming educational contracts that incorporate educational intelligence in a judicious way.

- **Delineation:** Learners' needs and curriculum priorities are constantly shifting, according to societal and market requirements, making it difficult to ensure the education content delivered remains relevant and actionable. Scope of this direction is to establish a ground of knowledge artefacts that can support founding of learning paths, allowing for the recalculation of each one participation into the learning process according to its overall validity. Cultural and societal diversifications should be taken in mind in order to unify content delivery towards local and global criteria, making feasible not only digital convergence but digital inclusion as well.

- **Identification:** Analytics can help spot critical trends and delineate key markers to design effective service delivery and drive digital transformation. Formative and summative evaluations can be utilized to conclude achievement of objectives while agents and personalized sensors may trigger alerts and reshape content delivery targeting atomic success. Tree shaped knowledge exploration shall formulate the performance of learners with endurance, critically evaluated towards recommendation systems and AI-assisted automata. Validation of learning process outcomes can be matched to market required skills and dexterities in order to link the education with the production.

The initiative under investigation introduced some of the above directions, due to resources shortage. Automation was introduced through the delivery method and the reporting feature. This enabled the

asynchronous participant to engage without coordination. Integration was attempted through the onboarding of simulation environments, though it had partial effect as there was no control on the outcomes in order to feed back to the learning path process. Acclimation was accomplished through widening the knowledge source pool, socializing the participants to key actors and content providers. Delineation was based on the formative syllabus of the module, along with referencing to professional regulatory framework and specifications. Identification was achieved with summative reports, like the ones used in the present study.

### III. TRAINING METHODOLOGY

The methodology of training on module delivery was a mixture of synchronous and asynchronous delivery. The synchronous delivery was supported in class while the asynchronous delivery was accomplished through educational portal. The interesting thing about this study is that synchronous participation was obligatory, while the asynchronous participation was on volunteer basis.

The content delivery followed the module's syllabus in a more liberate manner, meaning that it utilized knew technologies in training process. Thus, the educational material had been transformed into digital form and has been delivered with diverse formats such as documents, presentations, self-assessment questionnaires, practical assessments, multimedia, web sources, etc. This approach touched the trainees, that were keen on new technologies and elevated their participation according to the educational targets. Their performance had been enhanced and their satisfaction as well [15]. This is due to the adaptive nature of content delivery, supported through the learning path tool available of educational platform. The adaptive nature is achieved with the repetition of educational content through diverse forms as well as the leveling of the content delivery according to the learning pace of the participants.

The evaluation of the comprehension level of educational content is accomplished through self-reflection tasks. These tasks require participants to follow the content delivery along the educational path and assemble the accumulated knowledge through questionnaires of closed type questions. The participants could fill in the questionnaires multiple times in order to receive feedback on errored answers, and through multiple tries to reflect weaknesses and achieve better understanding. The questionnaires were split according to formal educational program into chapters, reflecting the educational material and scope. Five (5) chapter' questionnaires were developed with 41. 11. 17. 32 and 19 closed type questions. The questions were developed in diverse ways to promote critical thinking against memorization.

In the following responses collected as anonymized samples are presented, overall for learning path participation and per individual chapter tests separately. This was selected as educational strategy

in order to improve participants' confidence and capitalize their tendency to new technologies. As such, an on demand, educational targets oriented reimbursement practice was realized to motivate participants' engagement and commitment. Nevertheless, the soft approach to learning sphere dimension evaluation as and the volunteer participation basis had loosened control on lasting results, leaving the learning sphere enlargement back and only to those that felt keen and comfortable.

### IV. DATA PRESENTATION AND ANALYSIS

The data collected on this study are presented regarding success score, number of tries, time spent, and response profile.

- Scoring is metric of educational targets accomplishment, imposing the learning sphere dimension and commitment of the participants. Individuals' learning sphere dimension is a metric that presents the background of the participant regarding knowledge (primarily) as well as skill and statues, towards the educational targets. Commitment is a metric of the value given from the participants to achieve educational targets with higher markings throughout the educational process.

- Number of tries is an educational method to outperform scoring by self-reflection as well as repetition. It triggers the engagement of the participants as well as their learning sphere enlargement pane. Engagement is a metric of participation in the educational process, based on the satisfaction accumulated. Learning sphere enlargement pace is reflecting the rhythm with which participants absorb the knowledge towards educational targets accomplishment.

- Time spent is an educational method to deliver educational material in a personalized way. It reflects the learning profile of the individuals and their comprehension comfort. Comprehension comfort is a metric that indicates the appropriate pace of knowledge delivery to be accumulated by individuals. Learning profile represents the atomic performance that is reflected through time spent in conjunction with the repetition pattern. This is not feasible to be measured in class, as synchronous delivery leaves no room for personalization.

- Response profile is a metric of the level of engagement and commitment to the learning targets while at the same time a dimensioning of the learning sphere. The integrated experience in learning path is measured with overall time online, due to lack of more sophisticated sensing mechanisms.

All results support adaptive learning delivery by quantifying the capacity of the participant. This study analyses the learning profile of the participants as well as the effect of adaptive learning into the training process.



### A. Learning path

According to educational portal statistics, during the last five (5) years, from the 230 enrolled students only 26% presented independent learning motive by accomplishing the participation requirements of the learning path module. Namely, they spent time and effort to follow all the steps and accomplish tasks that consist of the learning path, that is lecture notes, multimedia insights, review questions and more. The maximum value of completion percentage was 90%, as shown in Figure 2. with average completion rate value of 17%.

The completion rate indicates that the participants' profile should be shallow in learning sphere dimension and strong in commitment. The participation rate indicates that participants' engagement was limited.

The participants are separated into twelve (12) groups and some individuals, as shown in Figure 4. In half cases completion rate scaled up to 40%, while in the rest cases, in four (4) remained under 20% and in two (2) exceeded 60%. The average completion rate fluctuates among groups.

The consequent years' values of 40% and above show that the method achieved to motivate the participants to participate (engagement). The limited completion rate is a result of capability to perform self-assessment parts without the requirement of time and effort consuming learning path (learning sphere enlargement), driving themselves directly to the evaluation criteria (commitment). Those results are aligned with Figure 2 outcomes.

Individuals' participation in self-assessment tests, within learning path or independently, was developed according to Figure 4.

- The overall number of participants for Chapter 1 was 109 with maximum 22. average 3.5. median 2 and minimum 1 tries.
- The overall number of participants for Chapter 2 was 60 with maximum 21. average 3.9. median 2 and minimum 1 tries.
- The overall number of participants for Chapter 3 was 60 with maximum 27. average 4.1. median 2 and minimum 1 tries.
- The overall number of participants for Chapter 4 was 75 with maximum 17. average 3.6. median 2 and minimum 1 tries.
- The overall number of participants for Chapter 5 was 65 with maximum 26. average 4.4. median 2 and minimum 1 tries.

The total number of Chapters' test participants is 369. a 6 times multiple of the learning path participants.

The participation statistics show that more than 50% of participants maintained their interest in self-assessment. The reflection impact was appreciated in order to repeat the task for higher scoring. The

individual's number of tries is descending almost with logarithmic scale, with average 3.5 to 4.4 tries per chapter. Median number of tries with value 2 was different from mode with value 1 try (same for all chapters) and that suggests that most of the participants respected the value of self-reflection trying at least two times to accomplish the tasks.

Chapters 2 and 3 were with the smallest extent in number of questions and content coherence requirements with previous chapters knowledge delivery, and as such the confidence performance is achieved with up to the limit of fifteen 15 tries. A sole participant exceeded this number of tries in both chapters. For the rest of the chapters the number of tires converge to the limit of 20 tries, due to the uncertainty of the participants.

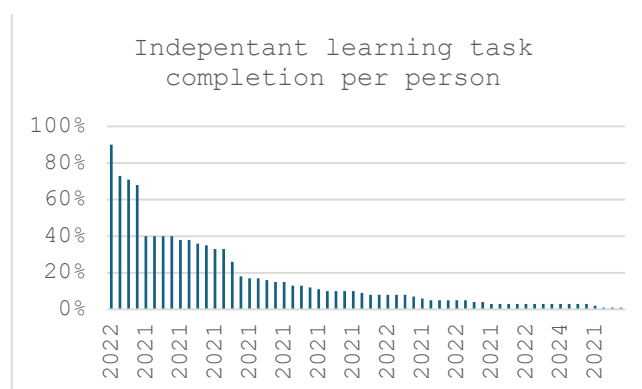


Figure 2 Learning path completion percentage by individuals.

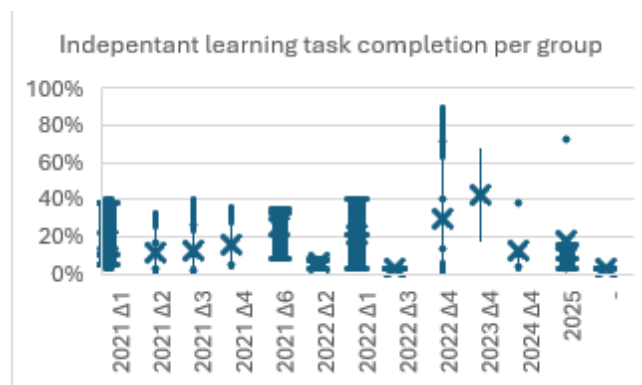


Figure 3 Learning path completion percentage by group.

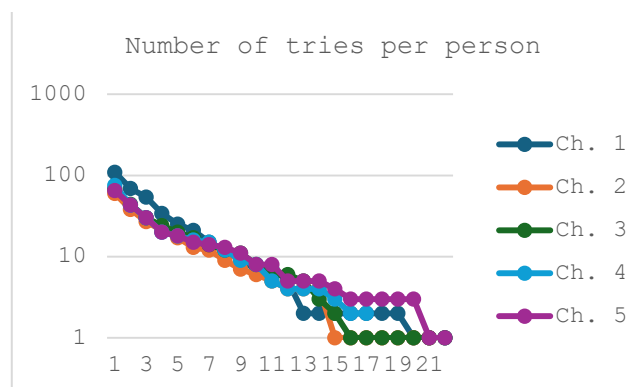


Figure 4 Learning path scoring for all chapters of educational content.

The detailed analysis of the chapters results show that participants among different years as well as different groups on the same year share similar characteristics. Engagement is achieved to a great extend and commitment is strong. Participants' learning sphere dimensions are discriminated against retries. Dominant learning profile is that of scoped engagement (commitment oriented) and not of learning sphere enlargement, as shown by the completion rate.

### B. Individual chapters tests

#### 1) Chapter 1 test

Chapter 1 self-assessment test was the largest in number of questions and at the same time the first the participants were introduced to. As such, it gathered most of their attention: 618 responses in total. Of them, only 393 were valid because a great number of submissions were bogus, caused by handheld devices' internet explorers or missed connections. Even more, some valid submissions had durations out of the expected range (1 and ½ minute per question, totaling to 61.5 minutes) and are regarded as result of holding the test alive for more time than actually performed (lost focus while in test). Those were 9 submissions, leaving for the analysis 384 valid ones.

Figure 4 depicts the scoring per number of tries for Chapter 1 self-assessment test. The majority of the scores are at the top of the graph, regardless of the number of tries. The average tries value is just under 7 tries. Horizontally, the scores can be clearly classified into 'higher' and 'lower' areas, with a visible gap between 40% to 60% throughout the whole length of the diagram. The trend line indicates that the scoring is improved by the number of tries.

The mode number of tries was 2 and the average 6.7, showing that the participants tried more than once to achieve the educational target (better score). This means that they were committed. Nevertheless, the exaggerated values of tries indicate that there are participants with low self confidence that seek valorization through score achievement. The horizontal score gap indicated that the participants are separated into two groups with diverse attitudes, those with comfort and those without. The gathering of the samples atop the score areas (in both 'higher' and 'lower') shows that learning profiles persist and provide similar outcomes regardless of the number of tries. The marginally inclining trend line indicates that the number of tries (repetition) improves the scores of participants (learning sphere enlargement).

In Figure 6 scoring is dense at the start of the horizontal axis (time) and for above 60% scoring and below 40% scoring as long as several minutes, spread almost uniformly. The linear form of points representation is a fault outcome of time rounding to integer minutes from the platform. Same as Figure 5, a vertical classification is obvious around the values gap 40% to 60%. This indicates persistence of participant comfort attitude both in retries and in time. Vertical classification can be drawn above the value of 7

minutes, diversifying graph into 'fast' and 'slow' areas. This indicates persistence of participants confidence classification, acquired through the repetition process. Trend line has negative slope, indicating that in general participants loosened grip on educational targets when time is passing.

The fast completion is a result of repetition as the participant maintains memories of former answers, minimizing time required to comprehend the content of the question. The average completion time (7.2 minutes) is less than expected (about an hour) because the participants gained familiarity with the advent of time and repetitions over the test. Also, because they present an attitude of scoped engagement, meaning that they are interested in achieving greater score (commitment) than improving their learning sphere dimension. Nevertheless, this dimension enhanced their engagement, that lasted from some minutes to an hour, even though the participants tempted to invest the least possible time. On the other hand, the number of tries indicates that the participants had low confidence for the procedure of learning sphere enlargement through learning path and preferred to validate their educational achievements (scoring) through continuous testing. This statue raises questions regarding the impact to the learning sphere enlargement and the endurance of the knowledge accumulated.

Figure 7 presents the evolution of time required to complete the test among consequent tries. The majority of the samples are within 50 hours interval, meaning the participants tended to accomplish the educational target with intense effort. The limited time among consequent tries enabled the memorization of the answers and the accomplishment with more confidence. This is obvious from the graph as the majority of tries lasted less than 10 minutes. This tendency is observed over all the length of the graph, meaning that the learning profile of the participants towards the test accomplishment manner remained the same throughout the learning path. This also means that the majority of participants felt comfortable with their comprehension level regarding the test requirements.

The trend line is almost straight, indicating no impact of the time between consequent tries to the duration of the tries. This indicated a learning profile statue that is indifferent regarding learning sphere dimensioning though committed in educational targets. This statue is affecting the engagement.

For the last analysis only 189 samples were used, as the rest had zero or invalid recordings.

The progress of time spent for the Chapter 1 self-assessment test with the given score is depicted in Figure 8, a reverse axes representation of Figure 6. The trendline indicates that there is a tendency to limit time with score achieved. This is a result of repetition that increases confidence as well as comprehension of the participant.

## 2) Chapter 2 test

Self-assessment test for Chapter 2 gathered 352 responses, from which valid was 224. for the same reason as it was for Chapter 1. Even more, 4 valid submissions had durations out of the expected range (1 and ½ minute per question, totaling to 16.5 minutes), leaving for the analysis 220 valid ones. It had fewer questions and lesser extent of the learning path, regarding the rest of the chapters.

Figure 9 depict the scoring per number of tries for Chapter 2 self-assessment test. The majority of scores are atop, regardless of the number of tries. The average tries value is just under the value of 6. The score converges to absolute with number of tries with border score value 9. The trend line indicates that the scoring has improved rapidly, regarding the other chapters' trend line's inclination, by the number of tries. In horizontal axis the samples are gathered at the 'higher' area.

The mode number of tries was 2 and the average 5.8 showing that the participants were committed to achieving the educational targets. The gathering of the samples at the 'higher' area indicates that the participants felt comfortable. The gathering of the samples atop the score areas through the length of the diagram shows that learning profiles persist and provide similar outcomes regardless of the number of tries. On the other hand, the number of tries indicates that participants had low confidence in the procedure through learning path (learning sphere enlargement) and preferred to validate their educational achievements (scoring) through continuous testing. The inclining trend line indicates that the number of tries (repetition) improves the scores of participants (commitment), and the higher inclination shows the confidence of the participants.

In Figure 10 scoring is dense at the start of the horizontal axis (time) and for above 60% scoring and below 40% scoring as long as several minutes. The linear form of points representation is a fault outcome of time rounding to integer minutes from the platform. Same as Figure 5, a vertical classification is obvious around the values gap 40% to 60%. This indicates persistence of learning profile in time spent and in number of tries. Vertical classification can be drawn above 2 minutes, diversifying graph into comprehension 'fast' and 'slow' completion areas. Trend line has negative slope, indicating that in general participants lost grip on the educational targets when time is passing (learning sphere shrinking).

The fast completion is a result of repetition as the participant maintains memories of former answers, minimizing time required to comprehend the content of the question. The average completion time (2.3 minutes) is less than expected (16.5 minutes) because the participants gained familiarity with the advent of time and repetitions over the test. Also, because they present an attitude of scoped engagement, meaning that they are interested in achieving greater score (commitment) than improving their confidence, and

probably their learning sphere dimension. This statue raises questions regarding the impact to the learning sphere enlargement and the endurance pf the knowledge accumulated.

Figure 11 presents the evolution of time required to complete the test among consequent tries. the majority of the samples are within 50 hours interval, meaning the participants tended to accomplish the educational target with intense effort. The limited time among consequent tries enabled the memorization of the answers and the accomplishment with more confidence. This is obvious from the graph as the majority of the tries lasted less than 3 minutes. This tendency is observed over all the length of the graph, alike Figure 7.

The trend line is almost straight, indicating no impact of the time between consequent tries to the duration of the tries. This indicated a learning profile statue that is indifferent regarding learning sphere dimension, though committed in educational targets. This statue is affecting the engagement.

For the last analysis only 98 samples were used, as the rest had zero or invalid recordings.

The progress of time spent on the Chapter 2 self-assessment test with the given score is depicted in Figure 12. The trendline indicates that there is a tendency to limit time with score achieved, just like Figure 8.

## 3) Chapter 3 test

Self-assessment test for Chapter 3 gathered 425 responses, from which valid was 279 (66%), for the same reason as it was for Chapter 1. Even more, 8 valid submissions had durations out of the expected range (1 and ½ minute per question, totaling to 25.5 minutes), as with Chapter 1, leaving for the analysis 271 valid ones.

Figure 9 depict the scoring per number of tries for Chapter 3 self-assessment test. The majority of scores are atop, regardless of the number of tries. The average tries value is over the value of 6 tries. The score converges to absolute with number of tries with border score value 20. Horizontally, the scores can be clearly classified into 'higher' and 'lower' areas, with a visible gap between 50% to 60% throughout the whole length of the diagram. The trend line indicates that the scoring is improved by the number of tries. In horizontal axis the samples are gathered at the 'higher' area.

The mode number of tries was 2 and the average 6.3 showing that the participants were committed to achieving the educational targets. The gathering of the samples at the 'higher' area indicates that the participants felt comfortable. The gathering of the samples atop the score areas through the length of the diagram shows that learning profiles persist and provide similar outcomes regardless of the number of tries. On the other hand, the number of tries indicates that participants had low confidence in the procedure



through learning path (learning sphere enlargement) and preferred to validate their educational achievements (scoring) through continuous testing. The inclining trend line indicates that the number of tries (repetition) improves the scores of participants, and the inclination quitter shows the confidence of the participants.

In Figure 14 scoring is dense in the start of the horizontal axis (time) and for above 60% scoring and below 50% scoring as long as several minutes. The linear form of points representation is a fault outcome of time rounding to integer minutes from the platform. Same as Figure 5, a vertical classification is obvious, indicating persistence of learning profile in time spent and in number of tries. Vertical classification can be drawn above 3 minutes, diversifying graph into comprehension 'fast' and 'slow' completion areas. Trend line has negative slop, indicating that in general participants lost grip on the educational targets when time is passing (learning sphere shrinking).

The fast completion is a result of repetition as the participant maintains memories of former answers, minimizing time required to comprehend the content of the question. The average completion time (2.9 minutes) is less than expected (25.5 minutes) because the participants gained familiarity with the advent of time and repetitions over the test. Also, because they present a learning profile of scoped engagement, meaning that they are interested in achieving greater score (commitment) than improving their confidence, and probably their learning sphere dimension. This statue raises questions regarding the impact to the learning sphere enlargement and the endurance of the knowledge accumulated.

Figure 15 presents the evolution of time required to complete the test among consequent tries. the majority of the samples are within 50 hours interval, meaning the participants tended to accomplish the educational target with intense effort. The limited time among consequent tries enabled the memorization of the answers and the accomplishment with more confidence. This is obvious from the graph as the majority of the tries lasted less than 10 minutes. This tendency is observed over all the length of the graph, alike Figure 7.

The trend line is almost straight, indicating no impact of the time between consequent tries to the duration of the tries. This indicated a learning profile statue that is indifferent regarding learning sphere dimension though committed in educational targets. This statue is affecting the engagement.

For the last analysis only 164 samples were used, as the rest had zero or invalid recordings.

The progress of time spent on the Chapter 3 self-assessment test with the given score is depicted in Figure 16. The trendline indicates that there is a tendency to limit time with score achieved, just like Figure 8.

#### 4) Chapter 4 test

Self-assessment test for Chapter 4 gathered 447 responses, from which valid was 259 for the same reason as it was for Chapter 1. Even more, 1 valid submission has durations out of the expected range (1 and ½ minute per question, totaling to 48 minutes), leaving for the analysis 258 valid ones.

Figure 17 depict the scoring per number of tries for Chapter 4 self-assessment test. The majority of scores are atop, regardless of the number of tries. The average tries value is just over the value of 5 tries. The score converges to absolute with number of tries with border score value 15. Horizontally, the scores can be clearly classified into 'higher' and 'lower' areas, with a visible gap between 50% to 60% throughout the whole length of the diagram. The trend line indicates that the scoring is improved by the number of tries. In horizontal axis the samples are gathered at the 'higher' area.

The mode number of tries was 2 and the average 5.5 showing that the participants were committed to achieving the educational targets. The gathering of the samples at the 'higher' area indicates that the participants felt comfortable. The gathering of the samples atop the score areas through the length of the diagram shows that learning profiles persist and provide similar outcomes regardless of the number of tries. On the other hand, the number of tries indicates that participants had low confidence in the procedure through learning path (learning sphere enlargement) and preferred to validate their educational achievements (scoring) through continuous testing. The inclining trend line indicates that the number of tries (repetition) improves the scores of participants, and the inclination quitter shows the confidence of the participants.

In Figure 18 scoring is dense in the start of the horizontal axis (time) and for roughly above 70% scoring and below 50% scoring as long as several minutes. The linear form of points representation is a fault outcome of time rounding to integer minutes from the platform. Same as Figure 5, a vertical classification is obvious, indicating persistence of this classification in time spent and in number of tries. Vertical classification can be drawn above 5 minutes, diversifying graph into comprehension 'fast' and 'slow' completion areas. Trend line has positive slop, contrary to previous ones, indicating that in general participants gained grip on the educational targets when time is passing.

The fast completion is a result of repetition as the participant maintains memories of former answers, minimizing time required to comprehend the content of the question. The average completion time (4.8 minutes) is less than expected (48 minutes) because the participants gained familiarity with the advent of time and repetitions over the test. Also, because they present an attitude of scoped engagement, meaning that they are interested in achieving greater score (commitment) than improving their confidence, and

probably their learning sphere dimension. This statue raises questions regarding the impact to the learning sphere enlargement and the endurance of the knowledge accumulated.

Figure 19 presents the evolution of time required to complete the test among consequent tries. the majority of the samples are within 50 hours interval, meaning the participants tended to accomplish the educational target with intense effort. The limited time among consequent tries enabled the memorization of the answers and the accomplishment with more confidence. This is obvious from the graph as the majority of the tries lasted less than 8 minutes. This tendency is observed over all the length of the graph, alike Figure 7.

The trend line is almost straight, indicating no impact of the time between consequent tries to the duration of the tries. This indicated a learning profile statue that is indifferent regarding learning sphere dimension though committed in educational targets. This statue is affecting the engagement.

For the last analysis only 131 samples were used, as the rest had zero or invalid recordings.

The progress of time spent for the Chapter 4 self-assessment test with the given score is depicted in Figure 20. The trendline indicates that there is a tendency to limit time with score achieved, just like Figure 8. Unlike chapters 2 and 3. participants tended to spend more time in test, as shown from the density of the samples on the right side of the graph.

##### 5) Chapter 5 test

Self-assessment test for Chapter 5 gathered 432 responses, from which valid was 286. for the same reason as it was for Chapter 1. Even more, 4 valid submissions had durations out of the expected range (1 and ½ minute per question, totaling to 48 minutes), leaving for the analysis 282 valid ones.

Figure 21 depict the scoring per number of tries for Chapter 5 self-assessment test. The majority of scores are atop, regardless of the number of tries. The average tries value is just under the value of 6 tries. The score hardly converges to absolute at value greater than 25. Horizontally, the scores can be clearly classified into 'higher' and 'lower' areas, with a visible gap between 50% to 60% throughout the whole length of the diagram. The trend line indicates that the scoring is improved by the number of tries. In horizontal axis the samples are gathered at the 'higher' area.

The mode number of tries was 1 and the average 5.9 showing that the participants were quite committed to achieving the educational targets. The gathering of the samples at the 'higher' area indicates that the participants felt comfortable. The gathering of the samples atop the score areas through the length of the diagram shows that learning profiles persist and provide similar outcomes regardless of the number of tries. On the other hand, the number of tries indicates

that participants had low confidence in the procedure through learning path (learning sphere enlargement) and preferred to validate their educational achievements (scoring) through continuous testing. The inclining trend line indicates that the number of tries (repetition) improves the scores of participants, and the inclination quitter shows the confidence of the participants.

In Figure 22 scoring is dense in the start of the horizontal axis (time) and for roughly above 60% scoring and below 40% scoring as long as several minutes. The linear form of points representation is a fault outcome of time rounding to integer minutes from the platform. Same as Figure 5, a vertical classification is obvious. indicating persistence of this classification in time spent and in number of tries. Vertical classification can be drawn for over 3 minutes, diversifying graph into comprehension 'fast' and 'slow' completion areas. Trend line has negative slop, indicating that in general participants lost grip on the educational targets when time is passing.

The fast completion is a result of repetition as the participant maintains memories of former answers, minimizing time required to comprehend the content of the question. The average completion time (2.9 minutes) is less than expected (28.5 minutes) because the participants gained familiarity with the advent of time and repetitions over the test. Also, because they present an attitude of scoped engagement, meaning that they are interested in achieving greater score (commitment) than improving their confidence, and probably their comprehension sphere dimension. This statue raises questions regarding the impact to the learning sphere enlargement and the endurance of the knowledge accumulated.

Figure 23 presents the evolution of time required to complete the test among consequent tries. the majority of the samples are within 50 hours interval, meaning the participants tended to accomplish the educational target with intense effort. The limited time among consequent tries enabled the memorization of the answers and the accomplishment with more confidence. This is obvious from the graph as the majority of the tries lasted less than 5 minutes. This tendency is observed over all the length of the graph, alike Figure 7.

The trend line is almost straight, indicating no impact of the time between consequent tries to the duration of the tries. This indicated a learning profile statue that is indifferent regarding learning sphere though committed in educational targets. This statue is affecting the engagement.

For the last analysis only 42 samples were used, as the rest had zero or invalid recordings.

The progress of time spent for the Chapter 5 self-assessment test with the given score is depicted in Figure 24. The trendline indicates that there is a tendency to limit time with score achieved, just like Figure 8.



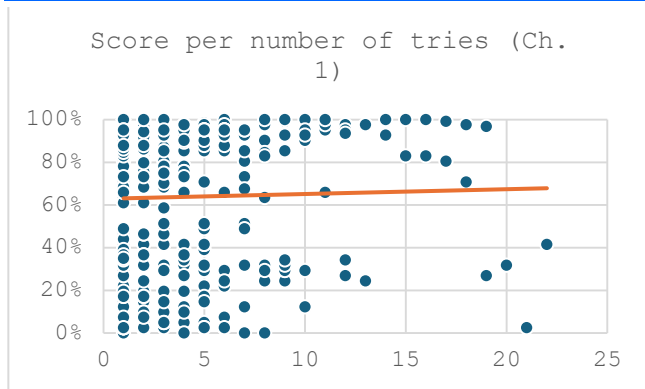


Figure 5 Score per number of tries for Chapter 1 test.

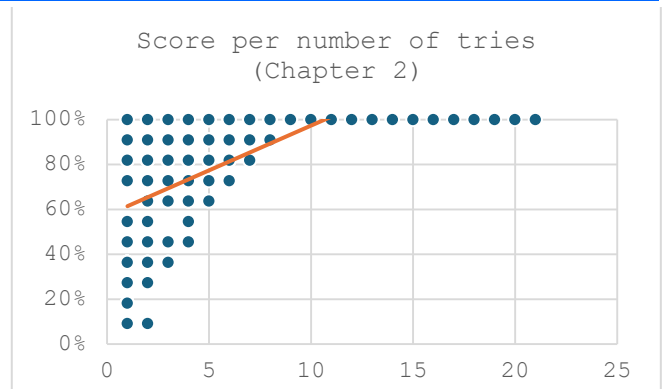


Figure 9 Score per number of tries for Chapter 2 test.

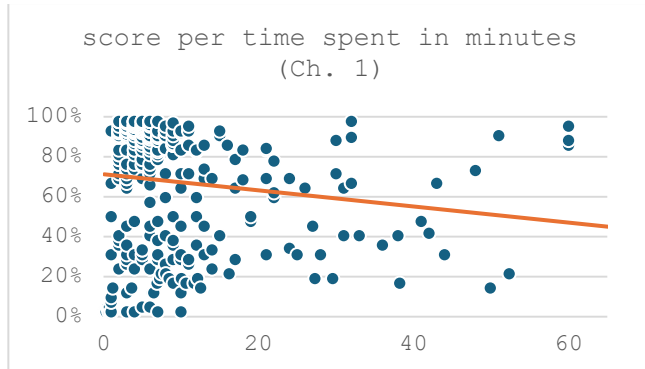


Figure 6 Score per time spent (in mins) for Chapter 1 test.

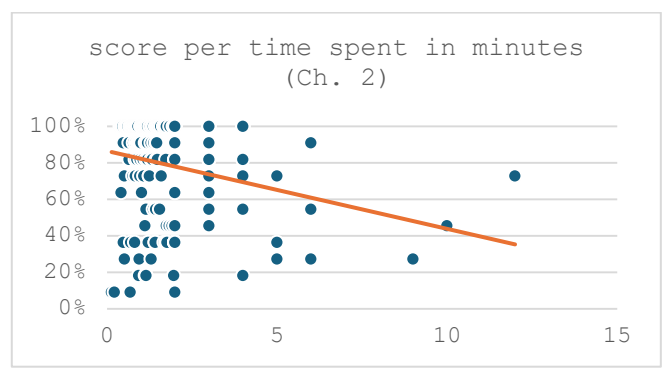


Figure 10 Score per time spent (in mins) for Chapter 2 test.

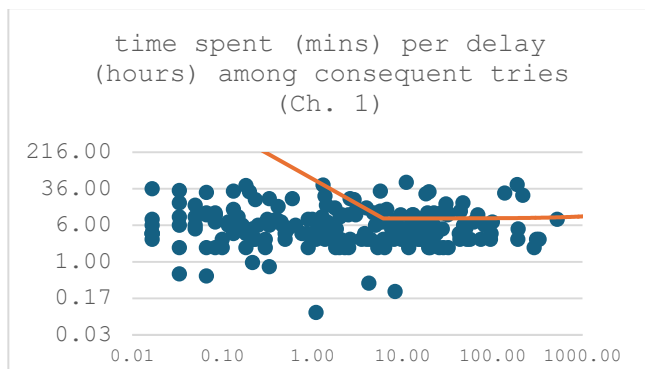


Figure 7 Time spent in minutes per delay (in hours) among consequent tries for Chapter 1 test.

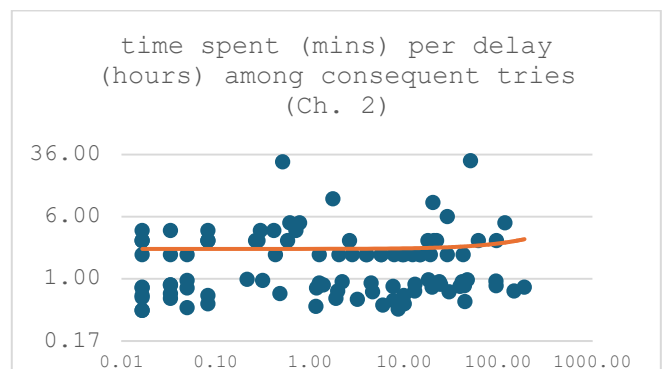


Figure 11 Time spent in minutes per delay (in hours) among consequent tries for Chapter 2 test.

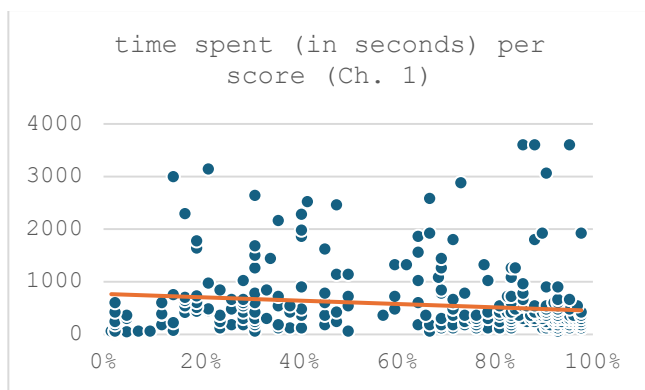


Figure 8 Time spent (in secs) per score for Chapter 1 test.

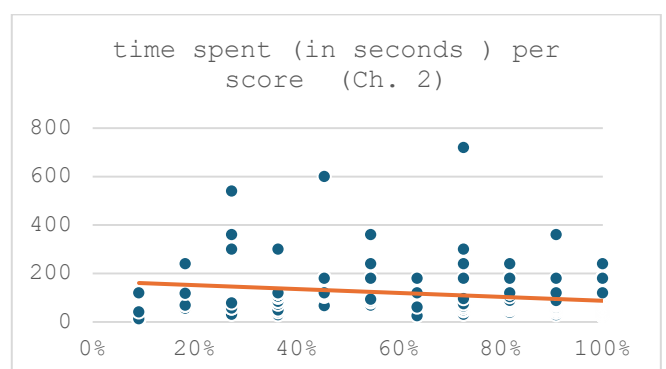


Figure 12 Time spent (in seconds) per score for Chapter 2 test.

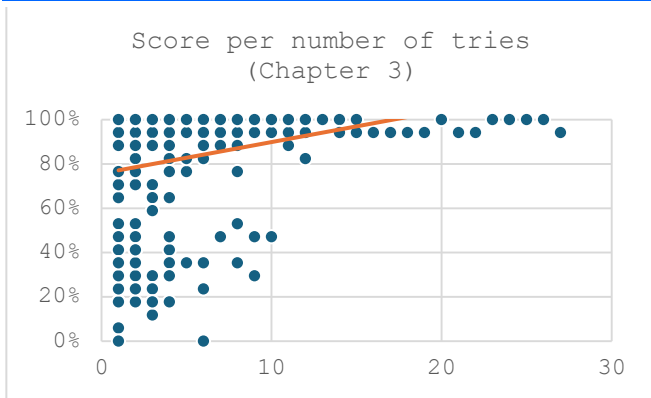


Figure 13 Score per number of tries for Chapter 3 test.

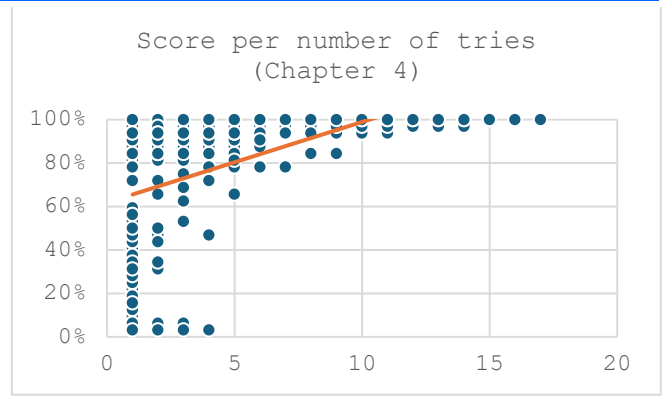


Figure 17 Score per number of tries for Chapter 4 test

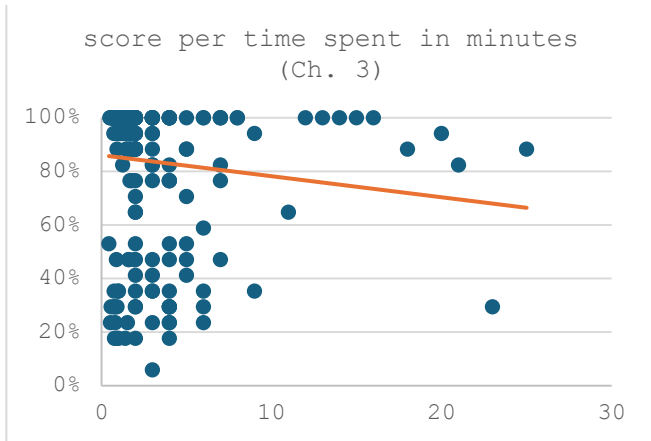


Figure 14 Score per time spent (in mins) for Chapter 3 test.

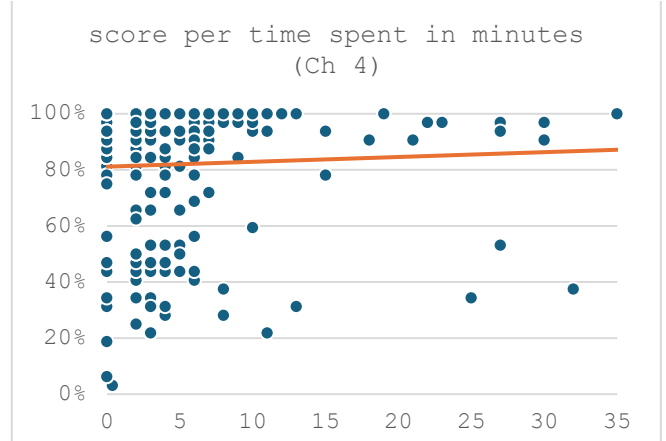


Figure 18 Score per time spent (in minutes) for Chapter 4 test

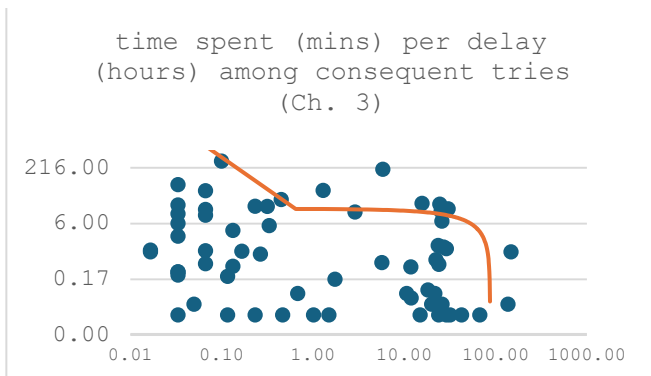


Figure 15 Time spent in minutes per delay (in hours) among consequent tries for Chapter 3 test.

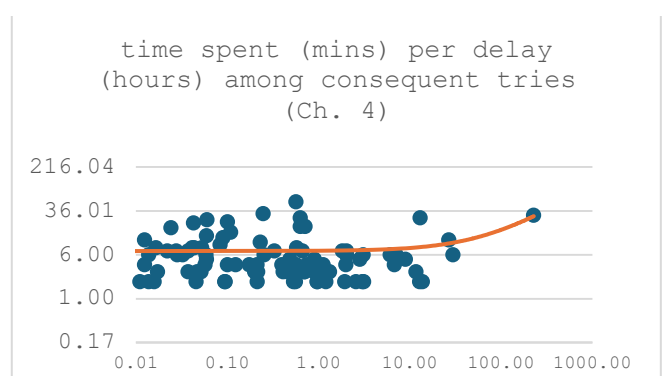


Figure 19 Time spent in minutes per delay (in hours) among consequent tries for Chapter 4 test

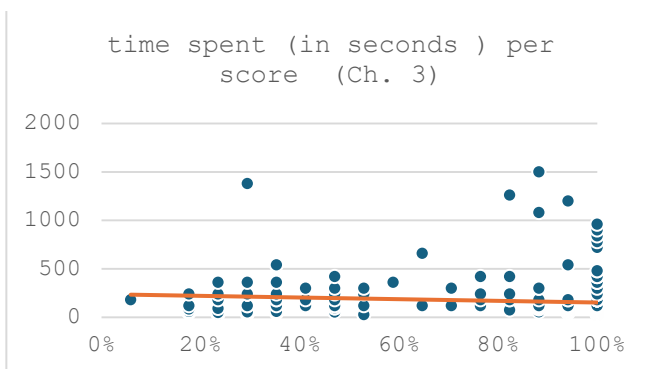


Figure 16 Time spent (in secs) per score for Chapter 3 test.

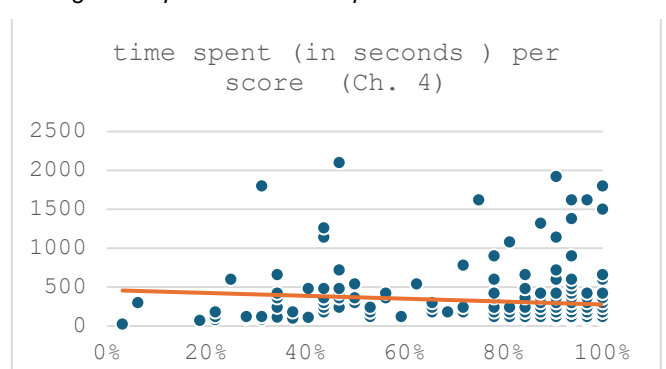


Figure 20 Time spent (in secs) per score for Chapter 4 test

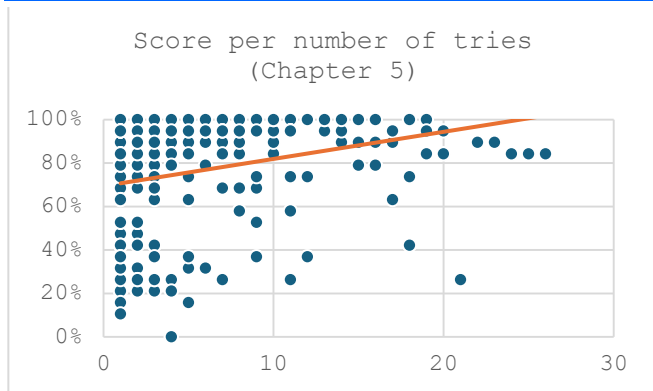


Figure 21 Score per number of tries for Chapter 5 test.

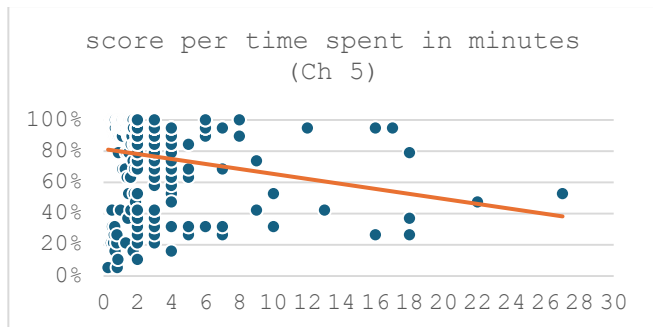


Figure 22 Score per time spent (in minutes) for Chapter 5 test.

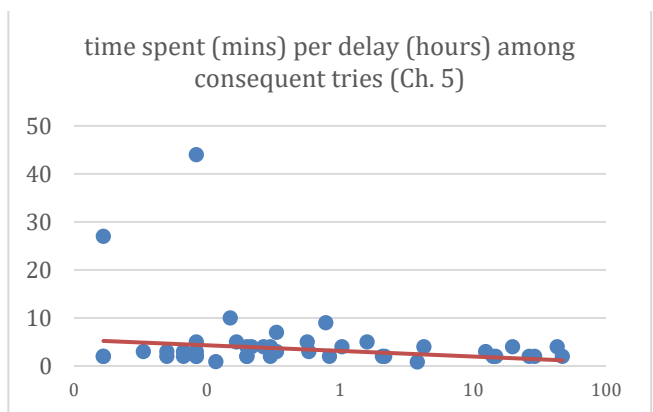


Figure 23 Time spent in minutes per delay (in hours) among consequent tries for Chapter 5 test.

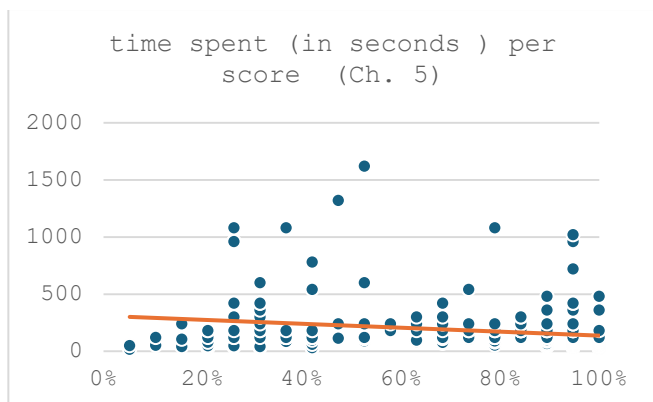


Figure 24 Time spent (in secs) per score for Chapter 5 test.

### C. Remarks on data collection

#### 1) Score achieved over number of tries

The general impression regarding score achieved over number of tries is that the repetition helped participants to improve their performance. Chapters 2, 3 and 4 tasks were more easygoing for the participants, allowing for the convergence of the scoring to absolute (100%) after several tries (15 in mean) for the great majority of the participants, as shown at Table 1. Trend lines in graphs of Figures 8, 12 and 16 show that clearly. In case of Chapter 1 (Figure 4) and Chapter 5 (Figure 20) the trend lines have opposite inclination, due to the fact that there were participants that felt uncomfortable with task and/or educational content and were left behind in score, regardless the number of tries. While in the case of Chapter 1 that would be acknowledged by the fact that it was introductory to the procedure and with the greater number of questions, there is no excuse for the concluding Chapter 5 case. This indicates a discomfort and potentially a comprehension lack due to knowledge sphere dimension shortage. This diversification is obvious in graphs, leaving a gap of about 20% in scoring. Still the 50%-60% gap may be noted through all Chapters' results, allowing for the characterization of the population as 'aligned' (above 60% scoring) and 'outlined' (below 50% scoring). A closer look at the samples may elevate the origin of this diversification more clearly.

The method of adaptive learning succeeded in maintaining a level of educational goals achievement at 70% in average for all chapters and over several years of application. This indicates the commitment of the participants towards the educational goals. It is accomplished through the repetition of the task (test and learning path) in voluntary basis. The average number of repetition tries were about one third of those required to excel in the tests. This indicates the scoped engagement of the participants towards valorization of results and not endurance (learning sphere dimension). Average scoring remained in the 'higher' scoring area for all chapters, indicating the comprehension comfort of the participants. Finally, the inclination of trend lines indicate that the background of the participants was improved over the consequent tries (learning sphere enlargement).

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TABLE 1 PARTICIPANTS' AVERAGE TRIAL NUMBER AND SCORING STATISTICS PER CHAPTER.

Chapter	Average score	Average number of tries	Tries to 100%	Low-high gap
1	62.18 %	6.72	-	40%-60%
2	71.18 %	5.77	9	-
3	74.76 %	6.27	20	50%-60%
4	72.55 %	5.49	15	50%-60%
5	69.59 %	5.87	>30	50%-60%
Average	70 %	6	15	50%-60%

TABLE 2 PARTICIPANTS' AVERAGE DURATION PER TRIAL AND INTER-TRIAL DELAY STATISTICS PER CHAPTER.

Chapter	Average test time (mins)	Average in between (hours)	Number of questions	Response time range (mins)
1	7.15	55	41	2-36
2	2.3	15	11	0.5-1 and 3-6
3	2.9	15	17	0-36
4	4.8	47	32	3-36
5	2.9	43	19	3-6
Average	4	35	24	3-6

TABLE 3 PARTICIPANTS' AVERAGE ONLINE TIME PER CHAPTER.

Chapter	Part. no	Av/ge test time (mins)	Av/ge number of tries	Av/ge in between (hours)	Online /person (hours)
1	109	7.15	6.72	55	2.89
2	60	2.3	5.77	15	1.20
3	60	2.9	6.27	15	1.32
4	75	4.8	5.49	47	2.82
5	65	2.9	5.87	43	3.23
Average		4	6	35	2.29

Average scoring remained in the 'higher' scoring area for all chapters, indicating the comprehension comfort of the participants. Finally, the inclination of trend lines indicate that the background of the participants was improved over the consequent tries (learning sphere enlargement) as shown in Table 1.

#### 2) Score per time spent

The time spent in tests tended to be minimized by the participants, not reaching the allocated time (1.5 mins per question). In average it reached about the one tenth of the expected duration. This indicates the comfort of the participants and the convergence to the educational targets. This is expected to happen as a result of repetition of test and educational content, as metric of knowledge sphere dimensioning. Still, the minimization of participation time imposes questions regarding the educational targets' endurance, as the repetition pattern showed short period of engagement

(35 hours in average per trial). This enhances the participants' comprehension comfort and commitment but limits the engagement and knowledge sphere enlargement.

The response time over all chapters follows a time limited pattern among 3 to 6 minutes, as shown in Table 2, regardless the number of test's questions as shown in Figures 6. 10. 14. 18 and 22. In Chapter 1 and Chapter 4 the most values remained within this time frame. This imposes the attitude of the participants regarding the engagement with the tests. In Chapter 2 response time frames are split with a visible gap roughly from 1 to 3 minutes. This indicates a persistent separation among 'fast' and 'slow' areas. The same gap can be noted for Chapter 3. where responses are spread all over the value area (0-36). While Chapters 2 and 3 tests are regarded as the easiest, this gap forming indicates the comprehension diversification of the participants, probably due to learning sphere limitations. This gap becomes less obvious as the difficulty of tests rises.

Another thing that should be taken in mind is the comprehension comfort and the retrieval interval. Namely, the easier the participants had gone with the test, the shortest the interval. Exception to this observation is Chapter 4 statistics, where retrieval interval followed Chapter 1 and Chapter 5 cases. This may be an outcome of the test's number of questions or the comprehension comfort of the participants. Another fact that supports this attitude is that long times of engagement becomes tiresome, leading to drop of scoring statistics, as shown by the negative slope of trend lines in Figures 5. 9. 13. 17 and 21 (Chapter 1 with slightly positive, almost neutral, due to the introductory nature to the process).

#### D. Research question achievements

##### 1) Level of participation

According to Figure 2, only 33% of the participants that followed the learning path endured for more than the average completion percentage. This means that 10% of the enrolled individuals tempt to become living followers of the independent learning modes (learning sphere enlargement).

The fulfilment of modules requirements was accomplished by following the learning path for all the five (5) chapters of module syllabus. The endurance of the participants is reflecting the level of their satisfaction as well as the adoption of the asynchronous, adaptive learning as a way of learning. Participation in individual self-assessments reached 40% (in average) of the enrolled students. This indicates that the majority of the learners lack confidence or motive in order to participate. Confidence is a result of limited learning sphere while motive is missing due to the attitude of 'learn on the job'.

The dominant learning profile or the participants emphasized on scoped engagement, due to participants potential learning sphere limitations as well as learning path limited integration with educational targets. The limited integration is an educational and technological drawback, as the available tools and techniques do not allow for the provision of simulation environments capable to facilitate and measure composite knowledge-skills-statues requirements. This is reflected in [15] where the participants lack acknowledgement of new technologies implication in practice.

The level of participation to individual tests was 30% (in average) of the enrolled students, a number close to that of the learning path participants. Contrary to attitude of the learning path participants, the majority individual test ones endured the test as well as in scoring. This proves the scoped engagement in learning profile of the participants.

### 2) Level of engagement

Time participants spent online, as shown in Table 3, reached 2.29 hours per person in average for all chapters. This figure is limited regarding the expected engagement towards learning path completion..

The attitude of the participants towards scoped engagement justifies the limited time expedited online. Nevertheless, it omits the scope of educational targets, namely the learning sphere enlargement, leaving questions regarding the lasting impact of the process. Solicit participants imposed questions and required guidance throughout the educational delivery period. This indicates a comprehension comfort that ought to be proved in formal evaluations.

### 3) Level of accumulation

Repetition of test questions helped the participant to acknowledge potential comprehension draw backs or knowledge gaps, and as such adapt, evolve and deliver better scoring. Most of the participants that endured by repeating the tests reached educational targets through high scoring. Nevertheless, this accomplishment should be regarded as partial and temporary, as the learning profile of the participants were not familiar with learning sphere enlargement practices.

Of particular interest is the scoring graph for single try shots from discrete participants, where the distribution covers almost the whole range of scoring, reflecting the acknowledgment of content delivery upon diverse participation profiles. Only a small minority managed to accomplish with the first time scoring analogous to that of multiple test takers. Those elite participants did not feel the need to follow the learning path.

Table 4 shows the results from intermediate evaluation of the participants through the module. This was an actual intermediate evaluation of the participants against the module completion. The

evaluation was based on knowledge sphere dimensioning with closed question test, due to its intermediate nature. The evaluation was based on the same material that the participants had the opportunity to train themselves. The results justified the outcome of the study as the average actual scoring was 67%, close to the study's outcome of 70% in Table 1.

It must be noted here that the presentation of self-tests' questions was linear, aligned with the educational content delivery progress, so as to promote participants' onboarding through familiarity, while in evaluation tests the questions' presentation was interleaved in order to minimize the memorization effect. The interleaving added a comprehension discomfort, that justifies a reduction in the success rate, like the 3% noted here. Nevertheless, the not lasting effect to the learning sphere, due to the scoped engagement profile of the participants, should be acknowledged as well for this reduction in scores.

The actual outcome of the educational method adoption may be illustrated in Figure 25. In this graph the evolution of intermediate evaluation is presented throughout a time frame when the new technologies were not completely deployed into educational delivery method and the participants tendency to use them was relaxed. With advent of time and availability of learning path and its components, the participants presented dramatic improvement, given the same requirements of the learning sphere dimension.

The improvement in intermediate evaluation scores is a result of educational method adopted, though the drawbacks in learning sphere enlargement prioritization were obvious at that era too (Figure 26).

Nevertheless, the final evaluation of the participants showed the shallow impact of their learning sphere. The final evaluation required knowledges, dexterities and statues throughout the educational delivery so as to reflect the learning sphere of the participants. The weak interest on the learning sphere enlargement that the participants demonstrated throughout the study was reflected here, averaging 23% in score. This is an attitude repeated over the years of delivery, indicating weak link among self-motivation and educational targets successful delivery.

TABLE 4 EVALUATION SCORE PER YEAR.

Year	Intermediate evaluation average score	Final evaluation average score
2021	52%	33%
2022	67%	9%
2023	78%	28%
2024	70%	-
2025	-	-
Average	67 %	23%

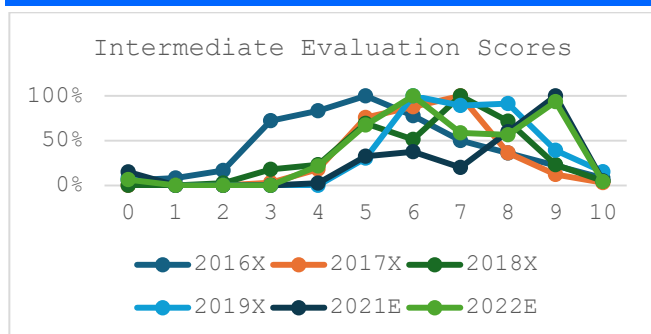


Figure 25 Progress' evaluation results (intermediate) for periods 2016-2022 [15].

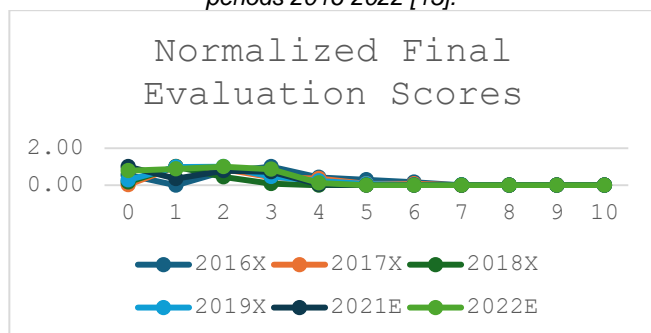


Figure 26 Progress' evaluation results (final) for periods 2016-2022 [15].

The same attitude is observed in previous years, when the adaptive learning method was not available to module's participants (Figure 26). This indicates a structural drawback regarding the achievement of the required learning sphere dimensioning from the participants with either methods. In order to overcome this drawback in knowledge, skills and attitudes required, a more sophisticated educational service delivery should be engaged. Namely, the incorporation of sensors that measure the proposed metrics along with other educationally sensible ones, and develop an integrated though personalized learning experience.

#### 4) Level of satisfaction

Participants took place in field study voluntarily, targeting to reflect their satisfaction. The field study lasted over the past five years and had more or less the same impact: above 75% of the participants approve the usage of new technologies and adaptive learning delivery, believing that their performance was improved by their usage [15]. The number of participants through out the years that the field study covers was analogous to the number of those joining the learning path, pointing out that an 'innovation movement' belief is formed within the learners.

#### V. CONCLUSIONS

Results of statistical analysis of the intermediate test of module progress evaluation showed that participants achieved progress through adaptive learning. The educational delivery method fitted to their learning profile allowing for the scoped engagement, mainly due to their comprehension

comfort, based on their learning sphere dimensions.

The integration of new technologies into the educational delivery method was well accepted and proved useful to participants. The tools available in educational platforms allowed for the implementation of learning paths, adaptable to learners' profiles. Nevertheless, the limited functionality and methods available restrained metrics and sensors deployment in order to support learner's integrated experience. Metering the results indicated that participants have certain profiles that can be classified regarding comprehension comfort, completion time, repetition persistence and inter-try interval.

From samples' analysis, a clearly distinguishable gap at the middle of evaluation scale segmented the comfortable to non-comfortable groups, both on number of tries and time spent. This marks the observation as structural in nature. Completion time was favored towards lower values due to learning profile of the participants, reflecting scoped engagement as well as learning sphere dimension indifference. Repetition persistence was also adopted by the majority of the participants, as they valued the valorization towards scoring. Finally, the time among consequent tries was limited to some days, proving the previous valorization and scoped engagement.

The results of the study were verified towards actual module's evaluations of the participants, and as such the research question, the usefulness of adaptive learning in educational delivery method, was justified.

The research question analysis was based on metrics available from the portal. Given the state of the art technologies and methodologies, an enhanced approach may be attempted, implementing a fully integrated adaptive learning environment. This imposes changes both in technological and educational basis, with introduction of targeted sensor and reflection methods as well as coordination [4].

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