Importance of maturity audit in virtual learning services for students' and employers' satisfaction

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Abstract

The article presents the authors' approach to the virtual learning capability maturity model (CMM). The emerging shift to different forms of the virtual education during and after COVID-19 lockdowns lead to many challenges and opportunities for all participators of the educational process – students, teachers, researchers, professors, and the administrative and technical staff. The authors are deeply involved into both synchronous and asynchronous learning organizational activities. Based on their 10+ years practical experience, they developed the CMM model for virtual learning and service for maturity assessment. The formal methodology of maturity assessment provides educational organizations with a clear roadmap for assessment and improvement of their virtual education services. Students and employers are provided with a transparent tool for assessment and choice of an educational organization for virtual learning. The developed CMM model and methodology are applicable and implemented for K12, high schools, universities, business schools, and professional training organizations. The practical implementation is demonstrated on an example of the 5th level of technical maturity – implementing specific mobile app for students with hearing impairs.

Keywords: Virtual learning, capability maturity model, assessment, CMM, digital learning, Petralex hearing aid, mobile app.

1. Introduction

1.1. Subject area

The virtual learning term has several definitions, one of which is "Distance learning conducted in a virtual learning environment with electronic study content designed for self-paced (asynchronous) or live web-conferencing (synchronous) online teaching and tutoring" [1].

Distance learning is known in different forms for many decades – if not ages, for example, in a form of learning by post. Meanwhile the growth and popularity of distant learning has started following the capacity of Internet connection bandwidth

and entered an emerged raise period during the COVID-19 pandemic lockdowns and their consequences.

A massive and fast shift to virtual learning leads to new opportunities and challenges for students, teachers, universities and other educational organizations in total. On one hand EdTech startups grow quickly as we demonstrate in Chapter II, students gained an opportunity to select the best suited educational organization anywhere. Educational organizations can easily attract a teacher, or a professor from any location now.

On the other hand, educational organizations faced a lot of challenges and issues due to unreadiness of technical facilities, staff – teachers, academic offices, technical services, students – to online self-paced work in new environment. Study materials are often non-adequate for virtual learning purposes, and many other challenges as well.

1.2. Existing background

The CMM institute is a worldwide recognized organization, which works out, support and continuously improve the capability maturity model [2]. In our work we strictly follow the basic 5-level structure for the Virtual education CMM.

Massive digitalization changes make huge impact on almost all areas of human activities [3]. According to [3] almost 60% of digital initiatives are successful, due to initiative, passion of stakeholders, and also process maturity in a company in total, while 40+% digital transformation projects and programs failed. Most of failures are proceeded from unclear goals of changes, lack of preparation, process maturity and integration, staff involvement and motivation.

In the educational sector the same results are identified, with the vast differentiation between educational organizations in their readiness – or maturity – for changes, digitalization. The authors examine and present those results in Chapter II. The current background. As types and levels of differentiation are dependent on many factors – for example, general process maturity; staff readiness and awareness of digital technologies; students' digitalization level; students' ability and capabilities for self-paced studies, current technology facilities, and many others – the authors has come to the conclusion that a transparent assessment methodology, which is based on a clear check list, can help educational organizations, students and their parents and future employers to make assessments of current level and define the growth and improvement points.

1.3. Solution

The authors developed the CMM model of virtual education maturity, which is aligned with the common capability maturity model design by CMM Institute, best pedagogical and methodological practices in the education area, and implemented it as a methodological approach for educational organizations and auditors.

The CMM model covers 360` of virtual education processes – teaching materials; teaching methodology; teaching staff readiness; technical facilities; students' support; marketing activities; feedback 360; and continuous improvement.

The CMM model contains 5 levels as defined in a classical CMM model, which are – initial, repeating, defined, managed and optimized.

The emerging introduction of generative algorithms - GPTs – leads to modifying the CMM model by introducing advantages and challenges of GPT implementation.

In the consequent chapter the authors demonstrate the practical implementation of the 5th maturity level for technical facilities on an example of implementing hearing aid mobile app for virtual learning purposes. This implementation provides an opportunity for students with hearing impairs to participate in any forms of study activities – campus-based, synchronous e-learning, asynchronous, or blended, as well as reach audio and video learning materials anywhere.

2. The current background

Distant learning started its history long ago with learning by post mails, radio, etc. In early 2000s the Internet-based studies appeared in a form of direct e-mails, forums, chats, access to simple equipment. We can highlight large software vendors official learning programs – by Microsoft, CISCO, Citrix, and others. E-books were delivered, and professional training centers provided RDP - remote desktop protocol – access to labs.

With expanding access to broadband Internet connection with HD/FullHD video, audio facilities, specialized traffic protocols, the on-line, virtual learning in all forms – synchronous or real-time, asynchronous, and blended arose.

In 2010s virtual learning developed at a native tempo, involving enthusiasts, and slowly expanding from traditional education to new educational forms. One of the first organizations, which started exploring a virtual (or online learning) in late 2000s was LERN (www.lern.org). It introduced evaluation model for educational organizations web resources as supportive tools for asynchronous learning, and further LERN participants introduced their experience in online approach.

In 2010s the various virtual learning approaches increased greatly in number of students, courses, programs, educational institutions.

According to Payoneer report [4]:

- The global e-learning market is expected to reach 350 billion dollars by 2025;
- Udemy Online Education Platform showed a growth in the number of students of up 425% from the end of February 2020;
- International educational platform Coursera has seen skyrocketing growth during the COVID pandemic's peak: more than 25 million registered people since mid-March 2019, which is 520% more than in the same period last year;
- 73% of teachers of professional skills (e.g. programming, digital marketing, IT, and others) do not have official teaching qualifications, and 77% of foreign languages teachers do have it;
- 77% of foreign language teachers have online teaching as the only source of income;
- 90% of all online educators would consider making e-learning the main source of income in the future;
- During COVID-19, 82% of educators teaching professional skills and 55% of foreign languages teachers noted an increase in the number of registrations for courses;
- 73% of Learning Providers indicate that their overall marketing strategies and focus changed or shifted in the last 6 months.
- 79% of Learning Providers are retooling or repurposing their existing programs.
- 64% of Learning Providers are rolling out new programs as a result of the Covid-19 pandemic.
- 69% of training is currently delivered by Learning Providers virtually, that's up from 17% since January 2020.
- 64% of Learning Providers forecast virtual instructor-led training to reach 64% in the long term 'post-COVID', decreasing at 5% from during 'peak-COVID' but remaining 47% higher than 'pre-COVID'.

In October 2020, the Leading Learning Providers Association (LLPA) surveyed its 33 members located in 55+ countries to understand the impact of the pandemic on corporate training. This survey was launched in October 2020, includes responses from 33 Leading Learning Providers across nearly 55 countries. The

sample also includes Leading Learning Providers with a range of organizational sizes and estimated annual revenues. Here are some findings from this survey.

The largest problems facing Learning Providers include:

- Adjusting to the new way of doing business.
- A decreasing number of students available to do training.
- Training is becoming a just-in-time service.
- Adjusting to the new model of hybrid delivery.
- Lack of qualified trainers.
- Setting up hybrid training rooms.

The exponential rise of EdTech and related startups demonstrates the interest and demand for this area.

Figure 1. Exponential growth of EdTech Investments.

Marr [4] clearly demonstrated the impact and implementation of AI, ML, blockchain for lea ring purposes.

The authors themselves are the founders and employees of a former startup company, which delivers a wide range of special apps, drivers and devices for hard of hearing people for learning purposes [5]. One of the authors had served as a startup mentor in an accelerator for 2 EdTech startups during previous years. All that supports our findings of EdTech high demand and growth. In Chapter 4 we demonstrate how EdTech solutions can impact growth of virtual learning for hard of hearing people.

Resuming this brief background overview, we can state that the education industry is struggling with serious changes -both enormous opportunities and challenges in all areas now. Having a strong clear foundation for assessment of a current state and defining the effective improvement strategy becomes a way out for educational organizations [6].

3. The Capability maturity model for Virtual learning

The authors developed the CMM model for the virtual learning (educational services), based on the classical 5 – level CMM model according to CMM Institute [].

The authors defined the following activity areas for the maturity model to develop the 360-grade assessment model:

1. General organizational approach defines the place of virtual services in an educational organization, and how the selected types – synchronous, asynchronous, hybrid – support the overall teaching concept.
2. Teaching methodology performs estimates if specific features for virtual teaching are developed and introduced.
3. Training materials section contains assessment criteria for preparation and delivery training materials, i.e. video lectures; presentations; labs, and others to students.
4. Teachers' e-teaching competencies provides assessment criteria for teachers and professors skills, competencies, and knowledge for delivering classes in an appropriate virtual mode – synchronous, asynchronous, or hybrid.

5. The Communication methods section introduces the assessment criteria in a crucial area of specific communications between students and teachers, students and administrative staff, students themselves.
6. The Communication tools section introduces criteria for maturity of technical tools and facilities, which enable convenient and appropriate communications between all stakeholder groups.
7. Students' involvement section defines assessment criteria for specific approaches and tools which enable virtual students involvement, collaboration and control of activities and progress. Also, those tools should support student's motivation and desire for learning.
8. Technical facilities section estimates readiness of various technical tools and facilities for different types of virtual learning – VLE (which stands for Virtual learning environment), including, but not limited to – video and audio recording and processing tools; online collaboration tools; virtual labs and practices environment; forums and chats; feedback tools; AI-based fraud and cheating prevention tools, and others.
9. Administrative staff readiness introduces maturity criteria for academic/dean office staff, technical support and other office employees and their work processes which enables continuous contact with and support for virtual students and teachers.
10. Transparent marketing section defines the basic principles of fair and transparent marketing, promotion activities for current and future students, teachers, partners, employers, and alumni.

3.1. The general approach to the maturity levels.

The general approach follows the basic CMM model, as presented at figure 2.

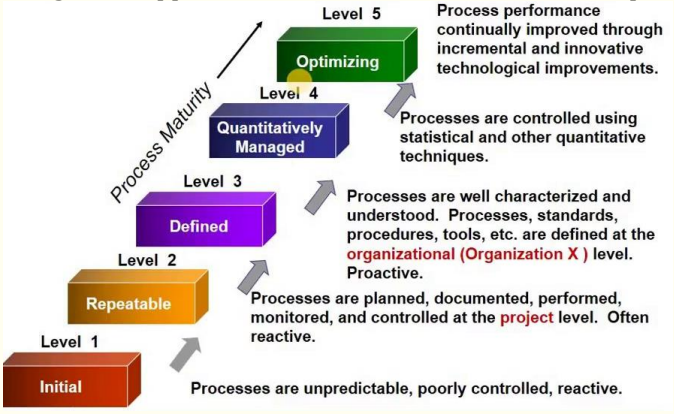

Fig. 2. CMM Institute 5-level maturity model.

We performed our own research iteratively in years 2020, 2021, and 2023 to define the specific features of a virtual learning for developing a CMM model. The research were qualitative, and based on observations, interviews with professors, teachers, academic staff members, and technology staff.

At level 1 we defined the following main features – attempts continuing "business as usual", which means using the same study materials and teaching methods. Sometimes paper-based materials were simply scanned and delivered to students. The lectures were the same as for class students, rather it is more difficult to keep online students' attention and motivation.

A citing from an interview, - "Not all the professors are happy with online teaching. Some are very enthusiastic and eager to use new tools and technologies, work around the clock, get out of the comfort zone, acquire new skills; while others are unhappy – mostly these are the professors who do not know how to teach online, who are scared of gadgets and digital world".

Level 2 is often sporadic and starts with creating a team of enthusiasts around a certain course or a group of related courses. The specific and widespread situation was observed during the pandemic lockdowns. The emergent shift to online first lead to a 1st chaotic level with huge disruption. Level 2 was reached based on self-experience of each institution, department. It is characterized by repeatable activities by each individual teacher/professor, or – in the best possible case – a department based on their individual experience.

Here are some citing from interviews:

"I use discord and zoom for video conferencing, as well as Skype for individual consultations. I upload my tests to onlinetestpad.com and quizalize.com. Some of my colleagues use InfoDa Moodle as the learning platform. E-mails are a form of group feedback for me"

Do you collect student's feedbacks? – "I try to. I use students' log for that purpose and the students have access to it, they can always ask questions about their marks and other issues. But the problem is that some of the students in the Uni are not interested in giving the feedback".

We can easily see differences in methodologies, tools applied, etc. The 2nd level is always an intermediate one.

Based on shared experience and its analysis the best practices can be formalized into organization-wide processes – methodological; teaching; technological, and others. Defining a shared common framework for virtual studies leads an organization to the 3rd maturity level.

Levels 4 and 5 are developing and are under pressure of fast changes in the technological, methodological, and behavioral areas. The authors suggest considering all areas as a complex, because of their interdependencies. For example, vast implementation of generative AI (GPTs) brings new opportunities in finding and analyzing information, changes teachers' and students' behavior and on the other hand it can lead to cheating, degradation of analytical capabilities; and requires new procedures and technical tools to identify inappropriate GPT usage.

Anyway, virtual learning aims at level 5 in the current world by focusing on continuous improvement, seeking for new opportunities, and facing new risks.

3.2. The Virtual learning capability maturity model.

In this section we present the current 2nd version of the CMM model for virtual learning.

This model defines clear qualitative criteria for each maturity level, based on the 10 areas, which are defined above. The 2nd version includes vast updates based on OESI audits performed; feedback from universities, business schools, high schools, professional training centers; community surveys; secondary research based on primary sources (see Chapter II), and quick checkups at the www.oesi.pro.

We start presenting the CMM with levels 1 – 2 as basic ones.

Features and attributes for virtual studies	Level 1	Level 2
General organizational approach	Ad hoc, based on classical class-based learning	Virtual learning is introduced as a separate type(-s)of service Specific responsible person(-s) and/or departments/teams are assigned
Teaching methodology	No specific methodology for virtual education process. Attempts to apply campus based methods as is	Defined and agreed preferrable methodology for online and/or virtual classes exists Best practices are extracted and discussed
Training materials	Existing for campus training or ad hoc prepared	Main learning materials are moved to e-format. Main requirements to e-materials, including video are defined Clear accessibility of study materials for students
Teachers/professors' e-teaching competencies	Teaching competencies are mostly class/campus based	Teachers - innovators shares their experience, mostly informally Best practices are shared Experiments comtimue Special requirements for e-teachers appear
Communication methods	Ad hoc, irregular, changing spontaneously	Communication points are defined Practices are mostly inherited from class/campus-based approach P2P and team communications exist, but can be sporadic
Communication tools	are chosen occasionally; often free or open source not aligned to the specific goals, students' and teachers' convenience	Preferred or recommended tools are defined. There is still no organization-based standard
Students' involvement	Spontaneous, attempts "doing business as usual" in class.	P2P communications with a teacher and Team communications exist, often sporadic. Control and grading are e-based, but practices are mostly inherited from class/campus-based approach. Feedback is gathered on a regular basis
Technical facilities	No common standards. Each teacher implements those tools, which she or he knows and uses in daily life. Grading procedures are manual	Some basic LMS exists. Often there is a combination of several technical tools Support is "on demand" Grading is partially built in LMS, partially manual Live sessions/streams appears Labs are partially delivered onine
Administrative staff readiness	Low, ad hoc. Reporting is manual. No or low support for students and teachers	Dedicated staff - both administrative and technical - appears Technical support is "on demand" but by a dedicated group Best practices are consolidated based on feedback loop
Transparent marketing	No specific marketing activities for online programs	Marketing dedicates a separate channel for research and promote online/virtual studies

Table 1. Levels 1-2 of the Virtual learning CMM

Level 3 is the first stable level, which can be applicable and considered as final for some educational organizations.

Features and attributes for virtual studies	**Level 3**
General organizational approach	The specific department(-s) is(are assigned Procedures are elaborated Quality metrics are assigned Measurements are performed Improvements are followed
Teaching methodology	Methodology types are defined and approved in accordance to educational organization goals Main processes are performed under approved policies and are repeatable, stable and resilient Internal requirements exist Dedicated syllabi for online courses Specific requirements for different types of virtual studies Best practices exist and actively sharted
Training materials	Instructor templates (presentations, labs, images) are prepared and delivered Video recording system is defined, tested. Training materials are developed manually or based on partially automated systems. Delivery is fully or partially automated Brand images, slide templates, background images and effects are delivered to instructors
Teachers/professors' e-teaching competen	Teacher's preparation roadmap exists Instructor’s training sessions established and recorded Teachers are provided with clear instructions and support Pre-class trainings on methodology and tools for teachers are introduced Trainer's inspections and audits are regular Ability to apply antiplagiarism tools
Communication methods	Omnichannel structured communication system, including synchronous, asynchronous methods; push/pull; team, p2p, one-to-many. Notification systems for all participants and roles; Teachers' and students' are ensured with communication trainings AI based systems are piloting
Communication tools	Video (synchronous & asynchronous) meetings Audio/podcasts asynchronous communications Forums, chats Feedback system Internal social nets
Students' involvement	Structured balanced communications, including: P2P Push (Teacher-to a student and Student-toStudent, Student-to-Teacher) Team Live online meetings Collaboration systems for team work, labs and practical activities
Technical facilities	Video recording system Live video system Video streaming Learning management system Feedback collecting and analysis E-materials storage Grading system
Administrative staff readiness	KPIs are introduced Metrics are continuously checked across KPIs Administrative departments (dean's/academic office; sales; technical; marketing; legal deps)activities are coordinated and partially automated. Administrative staff delivers 360-grade support to students and teachers - from methodology to technical facilities.
Transparent marketing	Students and candidates are provided with clear transparent information about virtual earning facilities Website, social nets contain separate sections on virtual learning

Table 2. Level 3 of the CMM – defined.

Levels 4 and 5 are based on a dynamic nature of education, and especially virtual education, and include continuous improvement and alignment with educational organization tactical and strategic goals.

Features and attributes for virtual studies	**Level 4**	**Level 5**
General organizational approach	All features from Level 3 are implemented. Additionally: Internal improvement sessions Internal audits External audits and/or certification programs	All features from Level 4 are implemented.
Teaching methodology	Methodology is aligned to strategic goals: - Students' satisfaction - Employers' satisfaction with graduates - Level of knowledge in the subject area - Educational organization rating and brand recognition - Professor and staff satisfaction (eNPS) - Attracting better candidates - Methodology is flexible to adapt to changes of VUCA world - Methodology can be adapted to innovative technical and software tools such as AI, VR, AR, Metaverses, but not limited to the mentioned	Methodology is aligned to strategic goals: - Students' satisfaction - Employers' satisfaction with graduates - Level of knowledge in the subject area - Educational organization rating and brand recognition - Professor and staff satisfaction (eNPS) - Attracting better candidates Methodology is flexible to adapt to changes of VUCA world Continuous improvement
Training materials	Teachers/professors react to students' inquiries in appropriate time, which is aligned with education tempo, tasks and audience	All features and attributes of Level 4 AND instant search for new approach
Teachers/professors' e-teaching competen		
Communication methods	As for level 3. Students and teachers can choose the best covenient for them	All features and attributes of Level 4 AND instant search for new approach
Communication tools		
Students' involvement	Deep students' involvement in collaboration with teachers and between students, and with industry Students are motivated to participate actively in discussions, teamwork, sharing knowledge and experience Schedule of assignments, labs, homework is balanced across courses to prevent overlap in topics and time	All features as for L4. Metaverse options for virtual presence, collaboration are implemented New features and tools are actively tested and their implementation is supported continuously Students are empowered to seek for innovative tools, introduce them, use actively and share with others
Technical facilities	As for level 3. Mobile access covers all features AI based bots are implemented for support purposes Continuous improvement activities Active research for new features and opportunities	All features as for L4. AI, AR, VR, Metaverses, gaming, etc. are actuvely introduced into classes and practices, and support facilities Instant search for innovations, fail fast approach
Administrative staff readiness	Monitoring of the environment and internal achievements for new opportunities on a regular basis. Updating KPIs to changing goals Actvely involve all participants - students, teachers, technical staff, alumnis Search for new methods and best practices and tools Proactively updates internal rules and procedures according to technological challenges	All features from Level 4 and Create new study tracks to attract alumnis Actively motivate technical, teaching staff for innovations Work on continuous procedure, staff improvments Form and participate in professional, business area communities
Transparent marketing	Marketing activities are multi-channel oriented: Students Future employers Professors and teachers Guest speakers Alumnis Marketing activities are focused on brand recognition and improvement All parties are actively involved into social net communications	All features of Level 4 AND Instant search for new approaches Marketing and promotion in virtual reality, metaverses

Table 3. Levels 4-5 of the CMM.

In chapter 4 the authors demonstrate the roadmap to the highest maturity levels on an example of implementing special applications for hard of hearing people. Those applications and the supportive methodology enable involvement people with hearing impairments into any form of the virtual learning – from synchronous online to asynchronous and any hybrids.

3.3. The assessment methodology.

The assessment methodology includes 2 levels – quick web-based self-assessment and audit – either internal or external.

3.3.1. The quick self-assessment.

The quick self-assessment is a simplified model, which includes 8 areas – teaching methodology, video materials, supportive materials, communication channels, technical skills, quality control, continuous improvement, and legal aspects.

The assessment follows 4-grade scale as weak, average, strong, and not applicable (or not exist). The quick assessment is an expert based.

Internal experts – academic office, professors/teachers, administrative and technical staff - performs their subjective estimates based on the CMM model and their own experience. The web-based tool [7] supports this process. The visual results are transparent and serve as a baseline for improvement decisions.

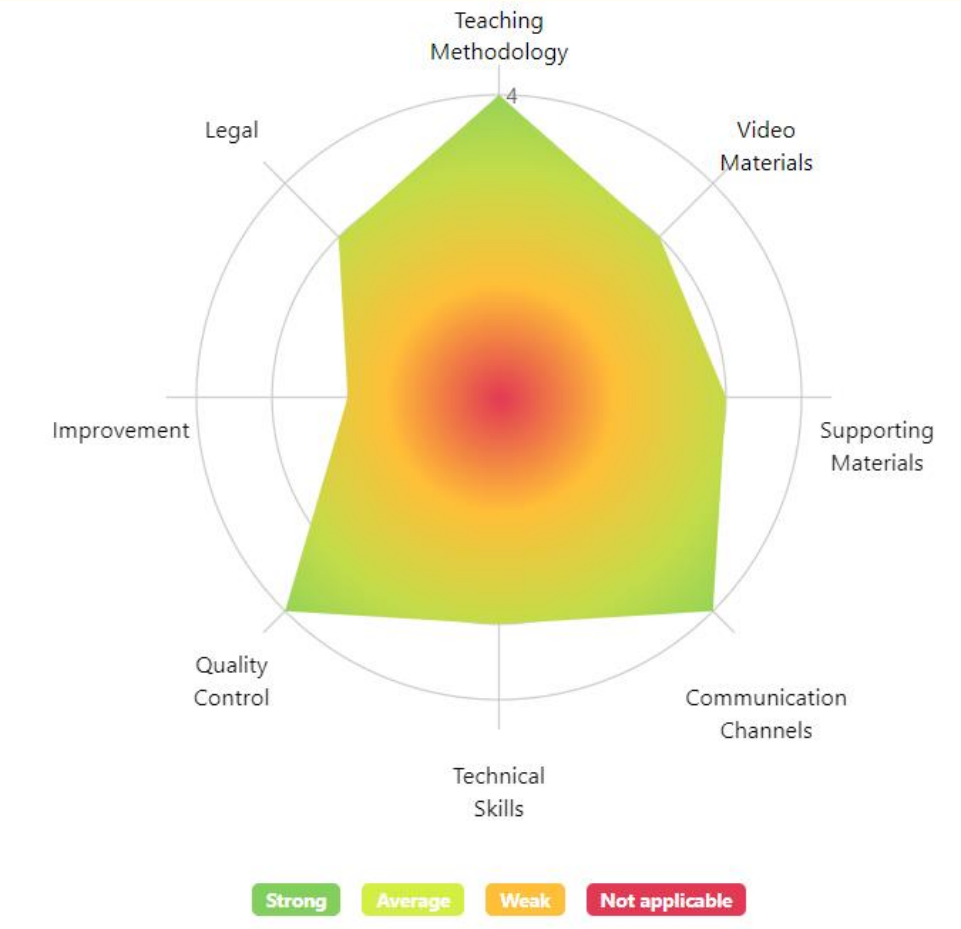

Figure 3. Quick self-assessment tool.

3.3.2. The assessment or audit process.

The audit or assessment procedure includes in-depth expert analysis in all 10 areas by independent internal (assessment) or external (audit) experts.

The procedure includes gathering of primary materials, , i.e. internal procedures, documents; course e-materials and video recordings; and any other applicable materials. Additional, but not mandatory activities include – attendance of an auditor at classes; asking any groups of stakeholders for additional feedback; performing a social net research.

The expert evaluation follows according to the CMM criteria, and results in detailed lessons learnt and improvement recommendations.

We are following the "best practice" concept in our audit (the approach is originated from Online Education Skills Institute). It is based on the following sources and baselines:

1. 360-grade degree, which means both internal and external assessment of each part of the online study process:
    - Teaching methodology;
    - Professor and lecture competencies;
    - Learning materials preparation and accessibility;
    - Student's involvement. Pre-course, in-course, and post-course support;
    - Technical facilities, including website, LMS, and other systems;
    - Administrative facilities and office staff competencies for online students' support;

- Marketing facilities.

2. Continuous improvement tools:
   - PDCA Deming cycle;
   - Total quality management;
   - Kaizen;
   - KiKaKu strategic improvement.
3. Continuous best practice aggregation, adaption, and delivery.
4. Post-certification control.

4. Mobile and desktop technologies for teaching people with hearing impairments

According to WHO (World Health Organization), more than 5% of the world's population (430 million people) suffer from various types and degrees of hearing loss. It is estimated that by 2050 more than 700 million people will have hearing problems. Hearing loss is more common among older people, however, among younger people, the problem of hearing loss is very relevant [8].

Hearing loss can be caused by many reasons, such as various auditory system diseases (otitis, meningitis, etc.), head and ear injuries, genetic diseases, excessive noise exposure, etc. [8, 9].

Hearing loss negatively affects a number of aspects of a person's life: communication, education, work, cognitive functions, etc. It is especially important to note the problem of hearing loss among young people, as it complicates the education process. For example, in developing countries, children with hearing loss and deafness rarely receive any education. Early hearing loss detection plays a key role in further treatment and auditory rehabilitation [8].

The advent of digital hearing aids (DHA) has made it possible to effectively perform hearing correction. Digital signal processing algorithms used in modern DHA are very diverse and include many functions: hard-to-audible frequency enhancement, adaptive filtering, echo cancellation, noise reduction, dynamic range compression, acoustic feedback suppression, etc.

Traditionally, DHA are designed as compact devices with the main function of hearing correction. The narrow focus of these devices causes their high cost, and also entails difficulties in maintenance and configuration - this requires the involvement of medical workers [9].

There are a number of limiting factors to the widespread use of DHA in some parts of the world. Such reasons include high cost, shortage of doctors, lack of motivation for their using [10, 11].

Various technical solutions are being developed to cover the majority of people suffering from hearing impairments. In particular, there are mobile applications that allow hearing testing without the involvement of specialists [10-15].

A possible alternative to DHA in recent years has been the use of hearing aid applications (HAA) based on smartphones [10-15]. This can be explained by the fact that the smartphone has the necessary hardware to perform the DHA functions: a microphone, an ADC and a DAC, a digital processor, an amplifier and speakers, as well as the ability to connect an external headset or headphones (both wired and wireless).

Some of the existing HAA position themselves as basic audio amplifiers, and vice versa, other applications try to get as close as possible to the functionality of modern DHA [10].

In particular, unlike DHA, some HAA allow a person to independently, without the involvement of medical personnel, perform a hearing assessment procedure, after which the application automatically adjusts to the hearing of a particular

person. At the same time, the hearing assessment procedure is close to audiometry used in medicine to test hearing [10-15].

Even though HAA is not a full-fledged replacement for traditional DHA, this kind of mobile applications have a number of advantages: [12]

A decreasing

- Flexibility of sound processing algorithms.
- Ability to customize the application to suit users hearing;
- Ability to apply a hearing correction algorithm for various kinds of multimedia content (audio books, music, online communication, etc.);
- Ability to use different models of headsets and headphones, both wired and wireless;
- Psychological comfort, since a smartphone is perceived by a person as an ordinary device, in contrast to the DHA.

Despite these advantages, HAA also have some disadvantages compared with DHA: [11, 13]

- Various latency from source sound to the output (headphones) on different devices;
- With high degrees of hearing loss, the effectiveness of hearing correction is lower

One of the popular HAA is Petralex, which is developed by the authors. This application implements an in-situ audiometry procedure (performed for the left and right ear separately) that allows the user to perform a hearing test, which is stored in a separate profile. The test results are used to automatically adjust the hearing correction algorithm. In addition, the user is given the option to select the target amplification formula (Berger, POGO, and NAL-R), allowing for finer application tuning.

Application work comes down to reading sound from a microphone (built-in or from an external headset), then processing it in accordance with the selected profile and other selected settings, then the sound adapted to the user's hearing is output to the headset or headphones (sound processing is performed for the left and right ears separately).

Sound processing is based on an analysis-synthesis system based on a digital filter bank. Hearing correction is carried out according to the hearing profile and the selected target amplification formula. The sound processing algorithm includes not only a hearing correction module, but also blocks for noise reduction and acoustic feedback suppression.

The application also allows user to create separate profiles for different acoustic environments, such as street or house. Since the creation of a new profile requires a hearing test, the test results will differ in various acoustic environments, and therefore the resulting frequency-dependent amplification will also be different. Thus, the user can use different profiles to achieve the best hearing correction depending on the external sound environment. [12, 13]

Hearing correction with HAA can be applied in the field of education. For example, if for some reason it is not possible to access the DHA, people with hearing impairments are forced to learn along with normal hearing people, despite their problems of sound perception. Due to hearing problems, the perception of acoustic information is very difficult, which negatively affects the speech intelligibility and affects the learning process. People are more focused on hearing what the teacher is saying than on understanding the information. In such cases, HAA can help people perceive sounds better and thus facilitate the education process (fig. 4). [5, 17]

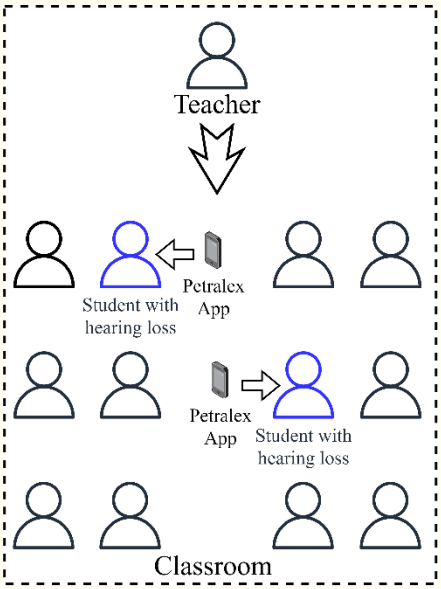

Figure 4. An example of using the HAA to teach in classroom the hearing impaired students with the normal hearing.

In addition to education in the classical format, HAA can also be useful in the form of virtual learning. For example, HAA Petralex is implemented not only in the form of mobile applications, but also as a program under Windows. The idea of the PC version working is identical to the mobile app. The difference lies in the fact that in the desktop version the Petralex driver creates a virtual audio device that implements sound correction to the user's ear. [5]

The key feature of Petralex desktop version of is that sound can be captured not only from a microphone, but also from any other sources, such as Skype, Zoom, an audio player, etc. Thus, sound correction to the user's ear can be useful for virtual learning (fig. 5) [5]. The user does not need to listen to what the teacher said, trying to identify the spoken word. In this situation, the strength and concentration of the student will be directed to understanding the information said by the teacher.

Figure 5. An example of using the HAA in virtual learning.

This is an example of applying new technologies for the virtual learning improvement and expanding inclusive capabilities. This approach aligns to the 5th maturity level in the CMM model.

5. Conclusion

The fast changes in all types of virtual learning, its enormous rapid development and rise in all areas from technology to methodology arise a lot of new opportunities and challenges for all involved parties – educational organizations, academic and dean's offices, teachers and professors, students, their families, employers, regulation bodies.

Structuring best practices as well as known issues can help a lot all mentioned categories, and shift educational organizations to the road of adopting, adapting and continuous improvement of an appropriate form of a virtual learning process.

In the article the authors demonstrated the classical 5-level capability maturity model for virtual learning. Each level is defined by clear qualitative criteria and can serve as a basis for an assessment and future improvement. The Virtual learning CMM is instantly developing and improving according to new experience.

The authors demonstrated the 5th CMM level approach to technological improvement – the solution which provides inclusive learning for people with hearing impairment.

Conflict of Interest

"The authors declare no conflict of interest."

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