The Effects of Multimedia Learning Materials Quality on Knowledge Acquisition

Maja Gligora Marković *mgligoram@veleri.hr*
Polytechnic of Rijeka
Rijeka, Croatia

Božidar Kliček *bozidar.klicek@foi.hr*
University of Zagreb, Faculty of Organization and Informatics
Varaždin, Croatia

Dijana Plantak Vukovac *dijana.plantak@foi.hr*
University of Zagreb, Faculty of Organization and Informatics
Varaždin, Croatia

Abstract

Different learning environments offer learners various kinds of multimedia learning materials (MLMs). Although the usage of multimedia has proven to foster meaningful learning, a multimedia resource will not necessarily contribute to the teaching-learning process unless proper attention is paid to its quality. This paper explores issues regarding the assessment of multimedia learning materials (MLMs) quality as well as the relationship between MLM quality and knowledge acquisition.

We present a research experiment that involves low-quality and high-quality MLMs implemented in the learning management system (LMS) Moodle of a polytechnic school course. The quality of MLMs was evaluated by means of the LORI assessment tool adapted for the purpose of this research. The analysis of research data shows that MLMs developed according to the principles of multimedia learning and principles for reducing cognitive load were perceived as being of higher quality than those not developed using multimedia principles. Furthermore, students' usage of high-quality MLMs during treatment resulted in better knowledge acquisition indicated by significantly higher scores in knowledge assessment.

Keywords: Multimedia Learning Materials, Quality Assessment Tool, LORI, Knowledge Acquisition.

1. Introduction

Multimedia is seen as one of the most valuable teaching media as it offers a combination of text, still graphics, animation, audio and video within a single technology that enables the representation of knowledge in a variety of ways [3]. These days teachers can use many forms of technologies (e.g. TV, computers, tablets, smart phones) and media (books, audio, video, multimedia) to enhance their classroom teaching. A positive influence of a combination of several digital media on learning outcomes has been proven in a number of studies, e.g. [1, 2, 15]. However, the production of multimedia learning materials (MLMs) does not necessarily contribute to the teaching-learning process since hardly any attention is paid to the quality of educational materials and pedagogical standards [6].

High-quality of multimedia learning materials entails that they are produced using design principles or guidelines established in appropriate theories and that they serve their intended purpose, i.e. facilitate knowledge acquisition. Nevertheless, a lot of developers of multimedia learning materials are not familiar with relevant research in psychology and education [19].

Also, it seems that insufficient focus is placed on quality assurance of MLMs, which results in materials that are not assessed by appropriate assessment tools. Leacock and Nesbit [12] suggested that instruments used to evaluate educational software packages may not be suitable for evaluating small learning objects. The problem of different definitions and scope of MLMs therefore needs to be addressed first: they can be regarded as smaller digital learning resources that combine different media and are intended for re-use [12], meaning that those learning objects do not depend on technical and educational settings. Alternatively, they can be a part of an e-learning setting and should thus be evaluated using a broader e-learning quality framework [6].

The study in this paper explores issues regarding the quality of multimedia learning materials and focuses on two goals: 1) assessing the quality of MLMs and 2) exploring the effects of using MLMs of different quality on knowledge acquisition. To achieve these goals, we first reviewed theoretical and empirical research on the influence of multimedia on learning, then examined the tools for quality assessment of MLMs and finally conducted an experiment with low- and high-quality MLMs. In the final section of this paper, we discuss research results and implications of MLM quality on the e-learning systems design.

2. Review of Previous Research

2.1. The Influence of Multimedia on Learning

There is a vast body of research that explores the usage of multimedia to foster meaningful learning. One of the most elaborate studies about the impact of multimedia on learning was conducted by Richard E. Mayer and his associates. They performed a series of experiments to confirm Mayer's cognitive theory of multimedia learning and to show benefits of using the twelve principles of multimedia design when developing learning materials [13]. In one of the experiments Mayer [14] established the importance of convergence of individual types of media such as auditory narration with visual animation to promote meaningful learning. Along with that, Mayer and Moreno proposed nine ways for reducing cognitive load in multimedia learning [16].

Other researchers also explored the influence of digital media representation on learning. For example, Alty et al. [1] showed that the sound-and-diagram media combination significantly outperformed text-and-diagram and text-only presentations. Similarly, Arguel and Jamet [2] experimented with static pictures and video presentations to investigate their influence on learning outcomes. They found that students who had learned from a combination of video and static pictures performed better in the assessment than those learning only from video presentations.

On the other hand, there are studies in which no significant evidence on the impact of different media modalities in the e-learning environment was obtained. The experimental study by Jenkinson et al. [11] was comprised of respondents' time-limited exposure to one of two treatments: e-learning modules with static graphics vs. animated graphics, preceded by a pre-test and followed by a post-test. Although in their study no significant difference between treatments was found in the quantitative data, significant differences regarding students' perception of the effectiveness of the media were identified in the qualitative data.

2.2. Evaluating the Quality of Multimedia Learning Materials

Evaluating the quality of digital multimedia learning resources is important for a number of reasons:

- design of multimedia learning resources is often not in accordance with relevant research in psychology and education [19], resulting in a large amount of multimedia materials of questionable quality that are stored in repositories or on the Web,
- searching for high-quality MLMs may be impractical or time-consuming [12],

- choosing MLMs for re-use does not have to be objective [13] since search engines implemented in some MLM repositories use certain quality metrics in order to get specific (ordered) search results [22] and thus depend on the validity of the evaluation tool used to generate quality ratings,
- criteria used to evaluate the quality of MLM can serve as guidelines for improving the design of multimedia learning materials [5], [18].

While there are numerous studies that deal with effects of multimedia learning, the quality of multimedia learning materials has hardly been investigated.

One of the rare empirical studies is that by Chen et al. [8], who explored the relationship between students' cognitive styles, quality of multimedia service access by the Internet (QoS) and quality perceptions of participants (QoP) of multimedia content. In their research, the quality of multimedia learning content was limited to the service of Internet access, which is only one of the attributes that should be considered within the quality of multimedia learning materials in general. This technological approach to MLM quality is also common in a number of other studies, e.g. [4], [6], [9], where technological standards were used for MLM development and assessment of their quality, without focusing on its pedagogical aspects.

Another issue in the evaluation of multimedia learning materials is that their quality is usually considered within the overall online course quality, as in the study by Sung et al. [20]. In their investigation of e-learning quality assurance, sixty-seven e-learning courseware applications were analyzed and evaluated for the purpose of e-learning courseware certification.

Bubaš et al. [5] describe such an approach as *course providers' perspective* in the process of e-learning quality assurance, which emphasizes transparency, quality control and standardization. Other aspects of quality assurance are *students' standpoint*, with a focus on effective presentation of content, promotion of interaction and greater achievement in learning [5], or *suppliers' aspect*, where market-boosting and cost/benefit issues are considered [11].

The aforementioned examples illustrate different approaches to researching the quality of multimedia teaching materials and their use in the teaching process. However, the relationship between the MLM quality and achievement of learning process outcomes are scarce.

2.3. Tools for Measuring the Quality of Multimedia Learning Materials

The quality of multimedia learning materials is usually measured by using evaluation tools like questionnaires or checklists, many of which are of questionable reliability and validity [19]. In selecting a tool for assessing MLM quality the scope of multimedia learning materials should be taken into account as an additional criterion so as to differentiate smaller independent digital learning resources ('narrower scope') from multimedia learning materials that are an integral part of an e-learning course ('broader scope').

In this paper, we consider multimedia learning materials (MLMs) as computer-based learning materials intended to be used for teaching or learning that are not dependent on the learning environment and can be presented online or offline. Thus, for the purpose of this research, we reviewed two available instruments for measuring the quality of multimedia learning materials with similar definitions of MLM: LORI [12], [17], [19], and QAMLM [6], [7].

Leacock and Nesbit [12] define MLMs as digital learning resources that combine text, images and other media intended to be reused in different learning contexts. They created an instrument to measure the quality of multimedia learning resources named *LORI (Learning Object Review Instrument).* LORI includes nine indicators or items for evaluation of multimedia learning resources. Every item is described with several dimensions pertaining to that item rated on a 5-point scale, where 1 means the lowest grade and 5 means the highest grade, and can be further described with reviewers' comments. The final score for MLM quality is calculated by averaging the ratings.

The other instrument for measuring the quality of multimedia learning materials is the assessment guide entitled *Quality Assurance in Multimedia Learning Materials (QAMLM)* developed by the Commonwealth Educational Media Centre for Asia. Two versions of the

guide exist: QAMLM 1.0 [6] and the revised QAMLM 1.5 [7]. In the latter version, the guide provides quality assurance rating tools for developers of MLM (e.g. designers, technical specialists, subject matter experts), individuals who will perform the evaluation of MLM quality (e.g. teachers, parents, administrators and librarians) and end-users of MLM (learners), respectively. The revised version also incorporates some parameters that enable evaluation of e-learning courses like reusability or information validity and updating, among others [7]. The assessment guide for evaluators of MLMs (Part B) in the v1.0 version contains 19 quality indicators which are scored on a five-point scale. QAMLM is more suitable for qualitative assessment of MLM quality [6] and should be adapted according to the context of evaluation [7].

3. Empirical Research

3.1. Research Design

The main goal of our research was to determine the quality of multimedia learning materials and to examine the relationship between MLM quality and knowledge acquisition. In order to explore these issues, we defined the following sub-goals:

- developing low-quality and high-quality multimedia learning materials,
- selecting and adapting the MLM quality assesment tool,
- conducting the experiment to measure the quality of MLMs and its effects on knowledge acquisition during a longer period of time.

Our main research question was: *(RQ) What are the effects of high-quality multimedia learning material on knowledge acquisition*?

3.1.1. Development of Multimedia Learning Materials

In this study, multimedia learning materials are regarded as independent learning resources. This means that they can be implemented as part of a learning unit on a CD-ROM or used in online learning that is not facilitated by a teacher. In our case, MLMs were implemented within a blended learning environment in LMS Moodle v.1.9 for the course 'Graphics, text and multimedia' which was delivered to 1st year students at the Polytechnic of Rijeka, Croatia.

All multimedia learning materials were developed according to the guidelines for developing interactive multimedia learning modules by Stanford University [10] and by following the *Quality Assurance Framework* based on the ADDIE model of instructional design [6]. MLMs were developed for two topics: 'Colors and the Use of Colors on the Internet' (MLM C) and 'The Use of Graphics on the Internet' (MLM G).

Two versions of each topic were developed: the low-quality version (LQ) and the high-quality version (HQ). Low-quality multimedia learning materials (MLM G-LQ and MLM C-LQ) contained only texts and static images. In addition, i n MLMs LQ learning goals were not indicated, navigation was available only through the breadcrumbs determined by the Moodle, pages did not have a title, important parts of the content were not emphasized with formatted text or a different font, multimedia was not properly used for the presentation of the content, and self-assessment was not available, to mention only some of their features. On the other hand, high-quality multimedia learning materials (MLM G-HQ and MLM C-HQ) presented the same learning content as MLMs LQ but with additional multimedia types: audio, video, animations and interactive simulations. Those were developed by applying Mayer's principles of multimedia learning [13] as well as principles for reducing cognitive load [16]. Processes and changing parameters, e.g. how a change in the *brightness* parameter affects the picture, were presented with video or animation as well as additional text. The latter was placed in the proximity of the animation to reduce cognitive overload, according to the spatial contiguity principle [16].

3.1.2. Selection and Adaptation of the MLM Quality Assessment Tool

Before conducting experimental research, we analyzed two available instruments for measuring the quality of multimedia learning materials, LORI and QAMLM 1.0. While the QAMLM assessment guide was still under revision when this research was performed, the LORI tool had already been validated in several studies [17, 21] and proven to be easy to use and time-effective [12]. The advantage of the latter lies in the quantitative measures, which allows for easier interpretation of results. Furthermore, it had been used by many educational institutions to teach learning resource evaluation as well as to perform evaluations within different educational models (e.g. in a collaborative environment) [12]. Thus, we decided to use LORI for assessing the quality of the developed MLMs.

LORI's dimensions are described by the following nine items [12, 17]: *Content quality* (veracity, accuracy, balanced presentation of ideas, appropriate level of detail), *Learning goal alignment* (alignment among learning goals, activities, assessments, learner characteristics), *Feedback and adaptation* (feedback or adaptive content driven by differential learner input or learner modeling), *Motivation* (ability to motivate and interest a population of learners), *Presentation design* (design of visual and auditory information for enhanced learning and efficient cognitive processing), *Interaction usability* (ease of navigation, predictability of the user interface, quality of the interface help features), *Accessibility* (design of controls and presentation formats to accommodate disabled and mobile learners), *Reusability* (ability to use the tool in varying learning contexts and with learners from different backgrounds), and *Standards compliance* (adherence to international standards and specifications).

We extended and adapted the original LORI after the pilot research conducted among fifteen teachers at the Polytechnic of Rijeka concerning their usage of MLMs in the classroom and issues concerning MLM quality. Based on their answers in a semi-structured interview three LORI items were extended with new statements. The reliability of the adapted LORI was tested during the analysis of experimental data indicating high internal consistency, as reported in Section 4.2.

3.1.3. Experimental Method Plan

The experiment was primarily aimed to collect data for achieving the objective of the research: to determine the quality of MLMs and the effect of using MLMs of different quality on knowledge acquisition.

It was comprised of: a) usage of multimedia learning materials in a blended learning environment and repeated knowledge assessment on selected topics and b) evaluation of multimedia learning materials quality.

In the first part of the experiment students enrolled in the first year of a professional study programme in Information Science used multimedia learning materials during regular classes in a computer laboratory. Since our intention was for every student to use both low-quality and high-quality multimedia learning materials, a within-subjects research design was chosen. In order to eliminate a possible effect of the preferred learning topic on knowledge acquisition, students were randomly distributed into two groups and assigned MLM C-LQ and MLM G-HQ (Group 1) or MLM C-HQ and MLM G-LQ (Group 2). The procedure lasted for eight weeks, during which three knowledge tests were administered for each of the two topics. In the first week a diagnostic test was performed with each group of students to identify their prior knowledge of the topics from the course syllabus, including the two topics of our research interest. Students were briefly introduced to the research study but were not acquainted with the objective of the experiment. They were also introduced to LMS Moodle. In the second week they used MLM C-LQ (Group 1) or MLM C-HQ (Group 2) in class for 45 minutes, with a knowledge test administered 10 minutes afterwards. The tests were comprised of 15 questions (MLM C) and 21 questions (MLM G), respectively, and evaluated both recall and comprehension of the given topic. Grades were assigned according to the following percentages of points acquired in the test, as defined by the Assessment Regulations of the Polytechnic of Rijeka: 1 – failing grade (less than 40% of acquired points), 2 – satisfactory

(40-59.9% of acquired points), 3 – good (60-69.9% of acquired points), 4 – very good (70-79.9% of acquired points), and 5 – excellent (80-100% of acquired points). In the third week, the knowledge assessment test was repeated. During the fourth week the groups studied the other topic, using MLM G-HQ (Group 1) or MLM G-LQ (Group 2), with a knowledge test administered as in the second week. In the fifth week they were re-tested on the second topic. During the sixth and eight week, the third knowledge assessment was performed, on the first and second topic, respectively. In the seventh week there was no class activity but students were able to interact with MLMs from their home.

The second part of the experiment was comprised of evaluation of the multimedia learning materials quality with the adapted LORI instrument that contained 50 statements. Evaluation was performed by randomly chosen Croatian teachers of informatics who examined the MLMs and assessed them in an online survey.

4. Research Findings

4.1. Demographic Data of Participants

A total of 141 first-year students, 105 of them male (74.5%) and 36 female (25.5%) participated in the study. Among them, 102 (72.3%) had previously used multimedia in learning. A vast majority of respondents (133, or 94.3%) had attended a computer science course in high school.

In evaluating the quality of MLMs 19 teachers were involved, 13 (68.4%) of whom were female and 6 (31.6%) male. Most respondents had between 3 and 5 years of teaching experience, with 16 of them working at a higher education institution. All respondents had been using multimedia in their teaching practice, 3 (15.8%) of them sometimes, 14 (73.7%) of them often, and two (10.5%) of them constantly.

4.2. MLM Quality and Its Effect on Knowledge Acquisition

Due to page limitation, we provide only partial research results focusing on MLM quality and its effect on knowledge acquisition obtained after the first knowledge assessment.

The analysis of data gathered in the evaluation of MLM quality with the adapted LORI showed that teachers evaluated MLM LQ as low-quality and MLM HQ as high-quality materials, which was evident in the average grade given to a particular MLM type. Figure 1 represents the average grades for MLMs of different quality.

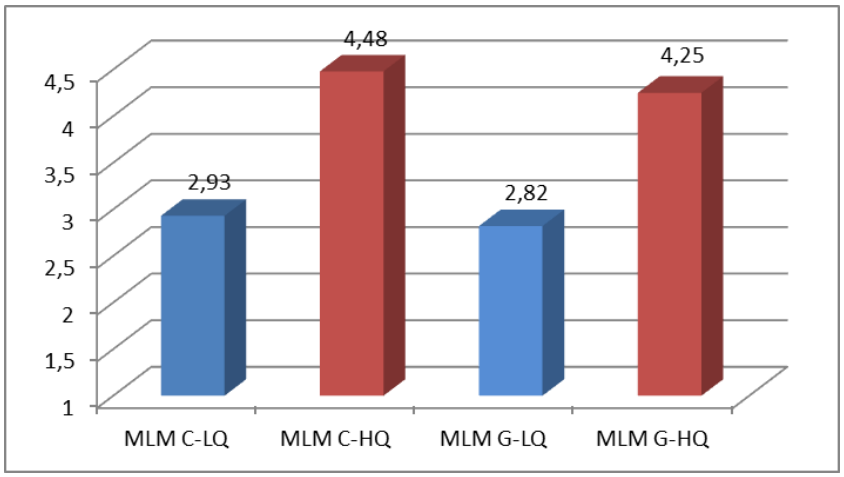

Fig 1. Average grades for MLMs of different quality

The reliability of the adapted LORI was determined by running the Cronbach's Alpha test in which all factors showed high internal consistency: 0.933 (MLM C-LQ), 0.947 (MLM C-HQ) 0.936 (MLM G-LQ) and 0.900 (MLM G-HQ).

Figure 2 represents the values for nine items of the LORI assessment tool for the topic 'Colors and the Use of Colors on the Internet' (MLM C). The smallest difference in the score (1.06) was identified for the *Content Quality* parameter, as both MLM C-LQ and MLM C-LQ contained the same factual knowledge related to the aforementioned topic. The biggest difference between scores (2.43) was found for the *Learning Goal Alignment* parameter, which, among other reasons, was due to the fact that in MLM C-LQ learning objectives were not defined while in MLM C-HQ they were clearly stated.

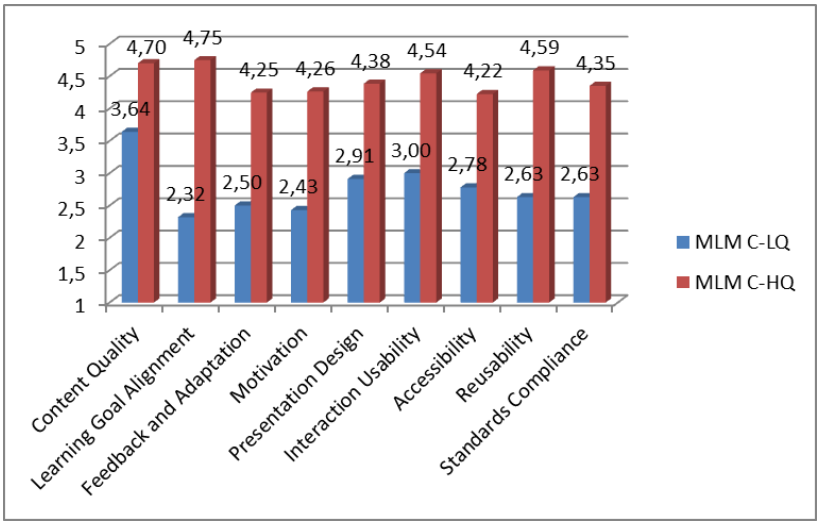

Fig 2. LORI values for MLM C

For the topic 'The Use of Graphics on the Internet' (MLM G), the biggest difference between the average scores (2.16) was identified for the *Standards Compliance* parameter (see Figure 3), since MLM G-LQ did not have embedded metadata and were not developed by using web technologies such as CSS or similar standards. The smallest difference between the average scores (0.87) was found for the *Accessibility* parameter since both types of MLMs were available via LMS Moodle which was accessed from computer labs equipped with a high-speed Internet connection.

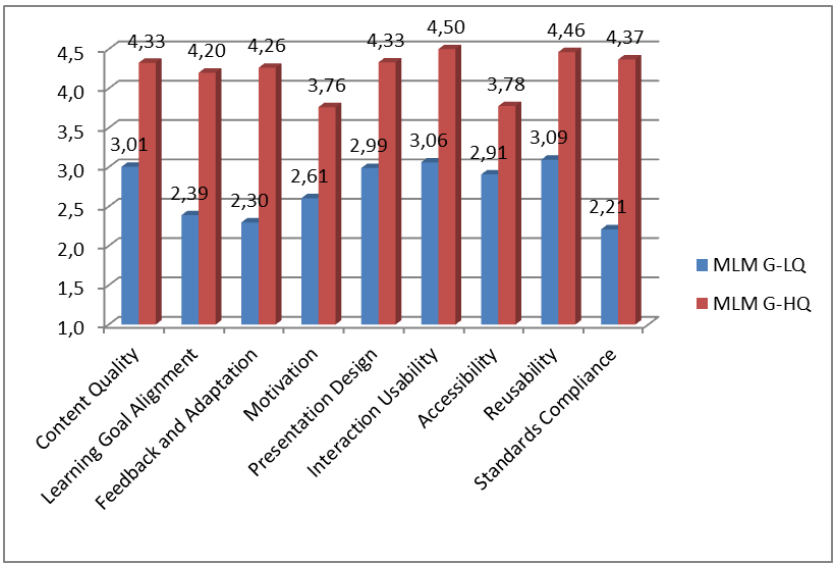

Fig 3. LORI values for MLM G

To determine the effects of MLMs on knowledge acquisition, we first calculated the average number of points and associated grades (ranging from 1 to 5) acquired after the use of MLMs and knowledge assessment. After that we verified whether there was a statistically significant difference in those parameters for MLMs of different quality for each topic (MLM C and MLM G).

Table 1 shows the results of the t-test for independent samples, where the number of points generated as a commemorative shape represents the amount of acquired knowledge. A statistically significant difference ($p < 0.01$) was found between LQ and HQ for both topics.

Table 1. Comparison of knowledge acquisition after the usage of MLMs of different quality and first knowledge assessment

Variable	N	Mean (max=32 points)	Std. Deviation	t	df	Sig. (2-tailed)	d
First knowledge assessment				-6.336	130.181	0.000	1.077
MLM C-LQ	70	21.43	4.292				
MLM C-HQ	71	25.54	3.337				

Variable	n	Mean (max=38 points)	Std. Deviation	t	df	Sig. (2-tailed)	d
First knowledge assessment				-7.475	139	0.000	1.262
MLM G-LQ	71	23.42	4.449				
MLM G-HQ	70	25.54	5.183				

Furthermore, Table 2 shows knowledge acquisition expressed as the average scores achieved, their percentages and the average rating for all MLMs. The percentage of acquired knowledge upon the use of higher-quality MLMs (C-HQ and G-HQ) was significantly higher (66.96% and 79.81%, respectively) than after the use of low-quality MLMs (C-LQ: 61.63%, G-LQ: 67.21%).

Table 2. Knowledge acquisition expressed by scores in points, percentage and average grade after the usage of MLMs of different quality

Variable	n	Score in points (average/max)	Percentage of acquired knowledge	Average grade (max. 5)
MLM C-LQ	70	21.43/32	66.96%	2.77
MLM C-HQ	71	25.54/32	79.81%	3.66
MLM G-LQ	71	23.42/28	61.63%	2.15
MLM G-HQ	70	25.54/28	67.21%	3.28

5. Conclusion

The design and development of high-quality MLMs is a challenging task, which explains why a lot of teachers are reluctant to invest their time and effort into them, especially considering that outcomes regarding MLM quality and knowledge gain are sometimes questionable. Moreover, most teachers are not sufficiently informed about recent research or guidelines for creating learning materials that foster meaningful learning.

The results of our research confirm that the usage of Mayer's principles of multimedia learning allow for creation of high-quality MLMs in a blended learning environment. In our experiment multimedia learning materials of different quality were created for the topics ‘Colors and the Use of Colors on the Internet’ (MLM C) and ‘The Use of Graphics on the Internet’ (MLM G) and were subsequently implemented in a polytechnic school course via LMS Moodle. The assessment of MLMs quality performed by teachers by means of the adapted LORI evaluation tool showed significant difference between the high-quality (MLM

C-HQ, MLM G-HQ) and low-quality materials (MLM C-LQ, MLM G-LQ) for every LORI item.

The adapted LORI assessment tool was validated as an effective evaluation tool with clear benchmarks for different quality items. It can be used to evaluate not only small learning resources, but also, as in our case, MLMs implemented in learning management systems. Items like *Feedback and adaptation, Interaction usability* or *Accessibility* evaluate dimensions that are part of LMS's functionality and as such can be used for evaluation of LMS as a product. However, the above assumption needs to be confirmed by additional research.

One of the limitations of the research in this paper regarding the assessment of MLM quality lies in a small number of teachers who evaluated MLMs, so additional research with a larger number of evaluators is needed in that respect as well. Also, evaluations performed by other stakeholders (e.g. students) might yield different quality estimation results since different stakeholders may emphasize different quality attributes, as suggested in [12]. Another potential problem involved in generalizing the results of our research might lie in different combinations of media types used in HQ and LQ MLMs with the same learning topic, which does not make those materials directly comparable. However, given that the learning content was the same in both MLM LQ and MLM HQ and that our goal was to asses the overall quality of multimedia learning materials presented within the online course and determine the effects of their quality on knowledge acquisition, we percieve this as a minor obstacle.

From the description of the experiment reported in this paper it is evident that students who used MLMs of higher quality acquired the average grade that was approximately one grade higher than that acquired by students who used lower-quality MLMs. This result was obtained in the knowledge assessment test taken shortly after the usage of MLMs in class. In our future papers we will show the results of knowledge assessments after a longer period of time during which students will also have had the opportunity to use and learn from MLMs in their spare time.

Positive effects of HQ MLMs on knowledge acquisition and achievement of learning outcomes as well as better grades for learners identified in our research indicate the necessity of investment in appropriate design of high-quality multimedia learning materials for use in the e-learning environment.

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