Using Mobile Technologies for Situating Bite-Sized Learning at the Workplace

Concepts and Recommendations for Implementation in Small and Medium-Sized Enterprises

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***Abstract*— Learning in the workplace is crucial for updating and upskilling the workforce to both new and existing employees. Given the limited opportunities for informal learning due to solitary work conditions or off-site locations, mobile devices like smartphones and wearables such as smart glasses can play a significant role. The aim of this paper is to investigate the extent to which mobile micro-learning can enhance work-related education, with a focus on lightweight, practical applications in learning-deprived environments. Comparative analyses are presented for mobile micro-learning approaches for smartphones and smart glasses based on recent studies, specifically examining their impact on learning and modes of interaction. Based on good practices of recent MML implementations, we present principles for implementation and offer lightweight proof-of-concept models for both handheld devices and smart glasses. This knowledge might be relevant for researchers, small and medium-sized enterprises, practitioners, and others involved in knowledge transfer.**

Keywords-work-based learning; informal learning; mobile micro-learning; smartphone; smart glasses; QR code; peer collaboration.

I. Introduction

Learning within the workplace plays a vital role in keeping today's workforce updated and improving their skills. However, in numerous occupations, chances for informal learning are limited. One example is remote working at the customer site or solitary tasks such as goods delivery. Mobile Micro-Learning (MML), which refers to bite-sized lessons accessed via mobile devices, can serve as a potent tool to boost informal learning in fields where learning opportunities are scarce [1]. While this previous research set the focus on classical MML based on handheld devices such as smartphones and tablets, we now extend our research and compare it against the potential that wearables, in particular smart glasses, offer for informal learning at the workplace.

The power of work-based learning for continuously updating workers' qualifications on the job [2] is a well-known fact, with the lion's share of learning being informal [3]. Informal learning takes place outside a prescribed learning framework (no organized event or package) and without a professional trainer [4]–[6]. It may be conceived as learning *in* work [7]: Embedded ("situated") in daily work routines [1][5], informal learning is initiated in a self-directed manner by workers and triggered by "an internal or external jolt" [5], i.e., on-demand when a specific work task is requiring it. Typical examples are observing, seeking help or feedback from others, discussing, trial and error, reflecting, or searching the intra- or Internet for information [2][5]. Informal learning can hence rely on the interaction with others ("social learning"), or on self-initiated study, practice, and experimentation ("learning by doing") [5].

However, in many occupational fields, the conditions for informal learning at work may be limited: In decentralized work settings (e.g., trains, trucks or delivery drivers, mobile care workers there is little direct interaction between workers). The same is true in highly mechanized settings with large physical distances between workers as well as in settings contexts where a product, such as a fire sprinkler system [8], must be maintained by a specialist working alone at the customer site, and in work environments with a lot of noise or high language diversity among workers – all of which is rather typical for blue-collar work [9], [10]. This hampers learning by observing, asking questions, and receiving feedback [11].

Due to tight schedules or high degrees of automation, many jobs offer little autonomy, which is seen as a crucial condition for experimentation on the job or other self-directed learning activities [10], [12]. Finally, access to codified organizational or external knowledge from the Internet [13] is difficult for those who have no permanent access to a stationary desktop computer. "Learning-deprived" jobs [11] typically suffer from reduced speed and intensity of informal learning at the workplace and jeopardize workforce upskilling.

This paper shows to what extent MML, i.e., learning based on bite-sized learning nuggets delivered by mobile devices [14], can help to improve work-related learning in learning-deprived environments. Learning based on bite-sized learning nuggets has been termed micro-learning or MML as it is typically delivered by mobile devices [14].

We propose a lightweight MML approach that integrates learning units into daily work tasks across both handheld and wearable devices, utilizing self-directed and peer-based learning methods. In this context, we also discuss the role of asynchronous and synchronous forms of MML. This paper surpasses the scope of previous work in [1], with respect to the devices and learning methods used, providing valuable additional insight into the capabilities of mobile-micro-learning at work. First, wearables allow a more seamless experience as learners do not necessarily have to interrupt their workflow while learning. Second, incorporating synchronous forms of learning facilitates direct interactions within the workplace or with experts, which is considered one of the main pillars of informal learning at work. The remainder of the paper is structured as follows: Section II illustrates existing concepts and good practices of micro-learning at the workplace, develops a typology of MML at the workplace, and explores the potential of different types of MML for informal learning. We then sketch design principles for lightweight approaches to anchor informal MML at the workplace and illustrate it with proofs-of-concept for both handheld devices and wearables such as smart glasses (Sections III and IV). In Section V, we discuss our findings, critically reflect on our approach and conclude with an outlook.

II. Related Work and Good Practices

A. Mobile Micro-Learning

Micro-learning typically consists of short learning nuggets (1-5 minutes) that are focused on one narrow topic and that are provided in rich, interactive media formats [14]–[16], e.g., (animated) videos, podcasts, job aids, cheat sheets, flashcards, quizzes or even gamified elements [17] and virtual reality nuggets [18]. Micro-learning is undertaken just-in-time when needed (“on demand”) [14]. In this context, mobile technologies are found to naturally match the concept of micro-learning and play an important role in its delivery [19], [20]. The use of mobile devices (e.g., smartphones, tablets, wearables) for learning anytime without being tied to a tightly-delimited physical location [21] is termed mobile learning [20][21]. In what follows, we subsume the above-mentioned learning practices under MML [16], [17]. Note that in the context of informal learning at the workplace, the concepts of micro-learning and micro-training are often used interchangeably, as both refer to short, often digital training or learning activities that can be easily integrated into daily work routines [24], [25]. In this paper, we stick to the term (mobile) micro-learning because it favors somewhat more the notions of self-directed learning that go beyond the mere acquisition of knowledge and skills.

MML has been found to increase learners’ motivation and improve knowledge retention thanks to reduced cognitive load and repetition [16], [20], [26]. At the same time, it is an efficient strategy to integrate learning into busy schedules, as well as for employees working in distributed settings [26], [27].

MML seems appropriate for and is widely used in informal learning settings [17], also if implemented at the workplace [16]. It stimulates self-directed learning, allowing learners to consume learning nuggets on-demand when they become aware of a problem or question in a specific situation [28], [29]. MML can be easily embedded in daily work routines and allows for informal work-related learning, also in deprived work settings as described in Section I (decentralized work, limited opportunities for interaction, lack of access to desktop computers). If properly designed, MML is not limited to the acquisition of narrow knowledge or skills, but may also enable higher-order learning such as analysis of a certain topic [28], which is particularly relevant for the experimental and reflective dimensions of informal work-related learning [30].

B. Typology of Mobile Microlearning at the workplace

Classical e-learning theory differentiates between synchronous and asynchronous forms of learning [31], [32]: Synchronous learning happens in real time, with learners and instructors participating simultaneously in activities such as live webinars, virtual classrooms, video conferences, and instructor-led training sessions. It fosters immediate interaction, feedback, and collaboration among participants. On the other hand, asynchronous learning is self-paced and doesn't require real-time involvement of others. Learners access pre-recorded lectures, online courses, reading materials, and assignments at their convenience, offering flexibility in managing their time and progress [ibid.].

In previous research and applications of MML, asynchronous settings dominate [22]. In many settings, it is even the expressed desire to partly or fully replace synchronous forms of learning with MML units [14, p. 792].

In this paper, we suggest the MML Matrix to broaden our perspective and differentiate between different modes of MML, depending on delivery mode and delivery device. Delivery mode depicts whether learning contents are delivered synchronously or asynchronously. Delivery device refers to either handhelds or wearables such as smart glasses which allow one to learn without having to interrupt manual work activities (hands-free). Figure 1 shows the MML matrix.

We do obtain a typology with four variants on how to implement MML. Please note that as this paper deals with the opportunities and challenges of MML for workplace learning, we strictly stick to the concept that MML units should not be longer than 5 minutes and that they should be situated in actual work routines.

As described above, *(1) handheld-MML* refers to MML based on handhelds such as smartphones or tablets. This is the most common type of MML. Synchronous *(2) mobile micro training (MMT)* where learners and trainers directly interact via handheld mobile devices is less frequent. Two potential explanations for this phenomenon are as follows: On the one hand, it may be simply too complex to organize a synchronous micro-training session that ultimately lasts less than 5 minutes – in particular, on-demand when employees need a certain learning bite. On the other hand, handhelds offer much less comfort and functionality for the users when interacting virtually as compared to a classical stationary desktop computer.

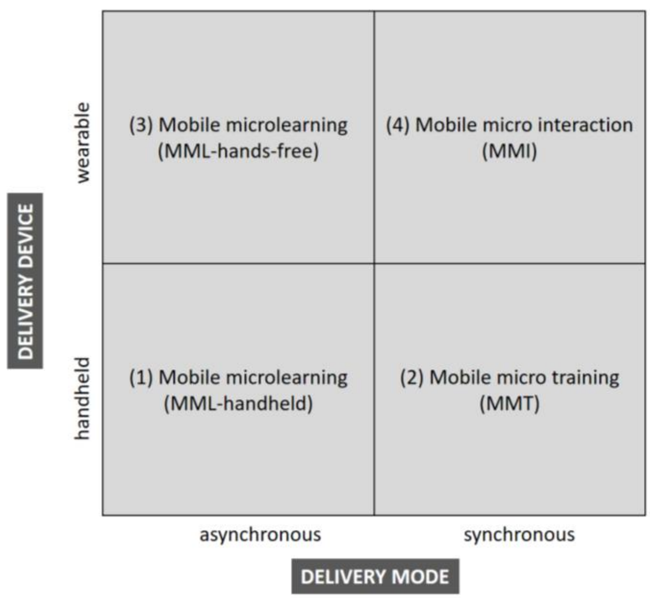

Figure 1. MML Matrix

As compared to handhelds, wearables, especially smart glasses, allow seamless integration of digital information and learning content into the user's working environment. A great benefit is that they enable on-demand access based on allowing hands-free interaction with digital devices so that learners can simultaneously continue with manual operations in their actual work task [33]–[35]. Smart glasses are frequently used for synchronous *(3) mobile micro-interactions (MMI)* between experts and employees with training on-the-job needs [36]. A prominent and widely used example hereby is the remote assistance of technicians maintaining machines and equipment at the customer's site [37]. As interactions are on-demand and normally consist of short instructions for the technicians, the definition of MML holds in these cases [36].

The last type, *(4) hands-free MML* refers to learning snippets that are delivered through a wearable such as a smart glass without synchronous interaction with a trainer. Many applications of Augmented Reality (AR) are based on this approach and can be found in diverse fields such as industrial assembly [38], healthcare or logistics, and supply chain management [39]. Note that it depends on the length and instructional design of learning snippets whether these applications fall under hands-free MML or not.

In what follows, we first study the most common type of MML, which is handheld MML, and evaluate its potential for informal learning in learning-deprived work settings (Subsection C). In the next step (Subsection D), we then study the chances of hands-free asynchronous MML as well as synchronous micro-interactions (MMI) for informal MML at the workplace based on smart glasses and discuss whether they also can be implemented in learning-deprived work settings.

Four aspects are central to our analysis:

- To what extent can learners self-direct their learning activities?
- Are forms of higher-order learning such as practice, experimentation, feedback, and reflection sufficiently triggered?
- How are learning activities "situated" in actual work routines?
- Do media formats and instructional strategies enable learning among workers who are not used to consuming longer verbal explanations or engaging in self-directed learning?

C. Examples of handheld-MML at the Workplace

Researchers and practitioners highlight the potential of MML for onboarding, ongoing professional qualification, and just-in-time learning [40]–[43]. Typical applications of MML at the workplace are compliance training in occupational safety [44] or information system security [34][35], building knowledge on new and existing products [47]–[49], or improving customer service [43]. Other, albeit less frequent are providing procedural work instructions, e.g., for installing or technical equipment [48] or in medical care [50], and machine use [51]–[53], as well as improving soft skills such as team management or goal setting [44][45]. Prominent examples from the industry are micro-learning initiatives for occupational safety at Walmart or Bloomingdale's that came with high participation rates and considerable savings [26] or the case of InterContinental Hotels Group to improve the management of complex customer service requests based on micro-learning which helped to reduce onboarding time for new employees from five to two weeks [56].

Recent scientific cases and evaluation studies on MML in real-life work settings cover a great variety of topics, e.g., how to keep costs in large building projects [57], dementia-friendly approaches for staff in neighborhood convenience stores [48][49], methods and approaches in pharmacovigilance [60] as well as a great number of examples from health and medical care [40][51]. Further attempts have been made in the hospitality sector [43], in logistics [62], in ICT [53][54], for public administration and NATO staff [30][55], for librarians [66], for school and university teachers [57][58] as well as for childcare workers [69], and even for employees of dairy farms [70]. Unfortunately, these examples are either not validated in a real-world setting, contain little information about the actual approach, rely on relatively lengthy learning units, or were published before 2020. Recent topical reviews provide even more examples of MML [17][21][24][29][57][61]–[63]. Still, the great majority of these studies were tested in an educational setting, only. In particular, empirical evidence on industrial applications of MML remains rare in this context [73].

Six studies were analyzed in-depth (S1 – S6, see Table 1) to investigate how companies and public organizations implement MML. All were conducted in real-work settings, underwent scientific evaluation with at least 20 participants, and contained sufficient details about implementation.

TABLE I. SELECTED MML STUDIES IN REAL WORKPLACE SETTING

Study	*Country no. of learners*	*Topic and learners*
S1 [60]	>100 countries (N>2000)	Pharmacovigilance (pharmacists, medical doctors, others)
S2 [57]	Norway (N=334)	Cost-efficiency in construction projects (project managers, engineers, architects and other)
S3 [47][48]	Japan (N=62)	Dementia-friendly customer care" (employees in neighborhood convenience stores)
S4 [50]	Australia (N>2000)	Clinical care and no-clinical topics (nurses, medical staff, non-clinical staff)
S5 [67]	USA (N/A)	Teaching skills and learning science (faculty at academic health centers)
S6 [61]	USA (N=26)	Point-of-care training for high-risk, low volume therapies (nurses)

The examples chosen rely on short learning nuggets (< 5 min) and primarily draw on rich, interactive media. Looking at studies published not later than 2020 allows us to get an overview of the state-of-the-art.

Three of the six examples analyzed come with a prescribed learning curriculum to improve specific competencies. S1 to S3 fall in this category. S1 consists of four modules, each comprising 6 to 8 short (2-3 min) videos and a final quiz at the end of every module [60]. Here, learning nuggets are not self-contained as content, practice, and quizzes are separated from each other [48][50]. In such a setting, learners are less expected to engage in self-directed learning but directed toward the predefined learning objectives in small steps, just as in classical e-learning courses [60, p. 1171].

The three other studies, both from the medical and health care field, allow for more self-directed learning: In S4 [50], a group of Australian hospitals provides the micro-learning format "Take 5 – learning for busy people" to their care, medical and non-clinical staff. Learners go through slide decks with condensed information about clinical and non-clinical topics. A learning nugget could explain the procedure in case of a "code blue" (a patient having a medical emergency such as cardiac arrest). Delivery happens browser-based by the internal website so that staff can search for learning nuggets whenever a problem or question arises during the work process. S5 applies an almost identical approach ("Take 5" on teaching skills and learning science for faculty members in academic health centers [67]): A website contains 41 Take-5 videos, jointly with other resources for learning and development. The videos were professionally recorded, prepared in conversational language, and not longer than 800 words. A blueprint suited for just-in-time learning was suggested and used: A teaser catching attention followed by expert advice. Animations were used to improve the retention of central issues.

However, searching indexes of available learning nuggets using a mobile phone as in S4 and S5 is unlikely to be effective in settings where workers tend to be less savvy in the self-directed use of large amounts of digital information.

In S6 [61], nurses can access point-of-care training for high-risk, low-volume therapies based on Quick Response (QR) codes affixed to work equipment. Scanned with a smartphone, they link to short training videos (2-3 minutes).

The preferred format used in the five examples of MML is slide desks, short video clips (sometimes animated), and quizzes. Only one study additionally uses animated videos and mini-simulation games [58]. Text-based information still plays an important role, as in some work situations, learners cannot play the audio, and videos have to come with transcripts, then [60].

The focus of the analyzed MML seems to be more on information and learning and less on practice, experimentation, and reflection. In study 1 [60], learners explicitly point out that they see included quizzes as a valuable instrument for self-assessment, feedback, and reflection, but would like to get more opportunities to practice. In S4 to S6, MML primarily relies on static microsites and video clips and does not offer quizzes or other activities related to reflection or practical exploration.

To sum up, up to now, the potential of MML for informal, work-related learning depicted in Subsection II is realized only very selectively. Instead of offering self-directed learning, MML is often implemented according to the same principles as classical e-learning courses that follow a prescribed path. Repositories of learning nuggets without QR tags in the working environment do offer a higher degree of self-direction in learning but still lack the anchor to actual working routines. Apart from using quizzes to self-assess learning progress, the examples analyzed do not offer strategies to enhance practice, experimentation, and reflection beyond the mere acquisition of knowledge and skills. Finally, as written or spoken text still is the main pillar of micro-learning units, learners with difficulties comprehending written texts and spoken language may be left behind.

D. Examples of wearable MML at the Workplace

The discussed research on MML above appears to predominantly focus on the handheld mobile devices of choice, and asynchronous learning without a trainer. However, in the context of small and medium-sized enterprises (SMEs), there are practical scenarios where employees need to maintain hands-free operations. This is particularly relevant in physically demanding environments, such as cramped technical spaces that necessitate specific postures, or in settings with hygiene constraints where workers handle substances like oil, which may not be compatible with handheld devices.

Smart glasses are emerging products in the field of wearable computing and have the potential to revolutionize jobs [74]. The features of smart glasses that are particularly useful for professionals include overlaying digital information on the physical environment and providing hands-free operation, which can offer task guidance, real-time information, and real-time collaboration. The use of smart glasses for workplace learning has been observed across multiple sectors, for instance in the food industry [75], healthcare [76], and dentistry [77].

Similarly to handheld-MML (see previous Section) publications specifically focused on on-demand MML in a practical setting are still limited, there are nevertheless results to be gleaned from the intersection of workplace learning and smart glasses. Databases were searched for in the title and abstract with the search string "workplace learning AND smart glasses." The databases included Web of Science (7 hits), ERIC–Ebsco (3 hits), IEEE Xplore (4 hits), and PubMed (0 hits) A narrower search string yielded no or fewer results. Most of the studies located using this search string were either conceptual or lab experiments. Other publications that were found focused on requirements and conceptual design, as well as a few publications that have also conducted practice-oriented research.

Hands-free MML. The learning outcomes from recent research involving smart glasses and MML are varied. Learning systems for training have been developed for example for procedural knowledge [78], [79]. Similar to MML with handheld devices, there is the possibility for self-directed learning, allowing personalized learning through scanning QR codes [79]. In a comparative study between handheld mobile devices and smart glasses in museum learning activities, wearable mixed-reality learning activities generally yielded better results than mobile handheld activities in terms of situational interest [80]. This result is promising due to the short-term engagement of situational interest, but the context of the workplace is often more constrained than a museum visit, warranting further research. Another example from the food industry showed that the use of smart glasses led to worse results than traditional video instruction [75]. However, this also seems to depend on the type of task and the form of training.

More practical examples are found in healthcare. In nursing, a pilot study was conducted using speech commands related to tasks such as: “Please select wound treatment”, and all tasks were achieved and experienced as supportive and helpful [8]. Smart glasses were also used as a tool to record real-life situations and used for remote education by synchronous live streaming or watching the recorded material at a later stage. Although the image and audio quality were sufficient, participants in the medical sector felt uneasy diagnosing clinical situations. Also, the connectivity of smart glasses and other devices remains a challenge [78], [80].

These studies indicate that both research and practical application are in the early stages. At the same time, it is clear that promising methods like scanning QR codes in handheld mobile learning can also be applied with smart glasses. However, learning outcomes via smart glasses need to be further examined in a specific context with clear task descriptions to compare results across different contexts and tasks. User perspectives also merit further investigation. While we see positive results in the medical field, remote observation was experienced as uncomfortable by students. This could be due to the specific patient situation concerning privacy, or the students' position having less experience compared to more experienced practitioners.

In summary, in the area of workplace learning with smart glasses as a form of MML, there is a need for more knowledge due to: 1) a lack of studies conducted in practice, 2) sectors in which it is being used, 3) the type of learning tasks, 4) functionalities of smart glasses being used, such as the screen, camera, or a combination thereof, 5) demands on the user, and 6) the objective and subjective learning experience.

Mobile micro interaction (MMI). While voice and video calling via smartphones or other handheld devices are no longer considered exceptional, smart glasses offer these functionalities in a hands-free manner. Smart glasses also allow camera use so that the receiver can view a first-person perspective or the user of smart glasses can receive screen-based instruction. Remote experts can assist smart glasses users via voice or video calling, offering task guidance and real-time information displayed on the screen. This paves the way for remote collaboration between experts and field workers. Remote guidance and collaboration have been developed for both augmented reality and virtual reality [81], such as assistance through visualization and 3D environmental reconstruction [82], or through remote observation and telepresence or teleconferencing as applied in healthcare [83].

The majority of examples in the literature on the application of smart glasses for remote collaboration are found in healthcare. The applications of smart glasses usually involve remote learning or collaboration via a video call [83] or screen-based instruction [84]. In a feasibility study involving teleconferencing, where an intervention team makes a video call with a remote expert paramedic, no differences were found compared to conventional on-site triage by paramedics [83]. This indicates in this specific use case that smart glasses yield results comparable to traditional methods of assessing clinical situations. Beyond teleconferencing, the use of the screen for instructions during the call has been also explored. By using WebRTC, a real-time communications framework for internet browsers and mobile devices, both video calls and custom data, such as drawings, can be facilitated [84] and WebRTC is open-source and available on GitHub [85].

Although proposals for applications have been made and several technical papers are available, there still exists a gap in knowledge focusing on 1) practical application with smart glasses 2) learning focus, 3) the use of smart glasses, and 4) lightweight requirements for implementation, which is particularly important for SMEs.

III. Implementation Approach For Hand-Held MML

Based on our findings in Section II and general design principles for MML [17], [28], [29], we provide recommendations on instructional strategy and technical implementation for a lightweight approach for MML that fosters informal work-related learning in learning-deprived occupational contexts. In this Section, we focus on classical forms of handheld MML. Additional recommendations for designing MML based on wearable devices will be elaborated on in Section IV.

A. Suggestions for Design and Implementation

A good point of departure for designing and implementing MML is the four principles for MML design summarized from earlier research by [28] and validated in a pilot test by [29].

- MML content should fit on the small screens of mobile devices.
- MML should address learners at the moment they feel the need to learn something. Connected to this, MML content should be short (no longer than 5 minutes).
- MML learning nuggets should be designed following an instructional flow that starts with an information snippet to provide an aha moment about the relevance (step 1), followed by instructional snippets with short exercises (quizzes, microgames, ideas for practice and experimentation at the workplace) and instant feedback (step 2). This instructional flow is based on an earlier model of Gagne [86], as cited in [29].
- MML content should be designed in a way that triggers interaction between the learner and the content (e.g., using practical and/or gamified activities).

These principles are an excellent starting point for designing MML for informal work-related learning. To make them even more suited to support and trigger informal workplace-related MML in learning-deprived occupational contexts, the following clarifications and additions are put forth:

- We favor short learning nuggets covering a single topic (1-2 minutes) to fit tight schedules, meet a single, specific question arising from the work context, and reduce cognitive load for learners. This is particularly important in the workplaces we focus on as they are often characterized by high time pressure (e.g., in health and care services) or a noisy work environment [53].
- To trigger learning from within work processes, several approaches [51], [87], [88] have found QR codes affixed to work equipment and locations to be a good practice to link to learning nuggets that might be useful in the respective work context (mobile tagging system).
- The instructional flow suggested helps to design learning nuggets that go beyond the mere acquisition of knowledge and that are still self-contained. However and as pointed out already by [28], besides opportunities for experimentation and practice, learning nuggets for effective workplace learning should also contain practices for reflection, which further enhances higher-order learning.
- Animated videos or visual, interactive work aids should be preferred over text-based and verbal information to enable learners who are less used to consuming large amounts of text or speaking another language.

Revising and complementing the original principles for designing MML content by [28] makes MML more lightweight: First of all, short videos preferably with visualizations and animations lower the barrier for learning for those with less favorable prerequisites for effective informal workplace learning. Second, self-contained learning nuggets that also comprise reflective activities help to enhance higher-order learning processes that are vital for successful workplace learning. Third and last, mobile tagging based on QR codes is a strong trigger to engage in informal learning activities when encountering questions and challenges in the work process.

However, we want to point out that due to its anytime-anyplace nature, asynchronous MML offers by nature only limited potential for learning through experimentation and practice at the workplace (“learning-by-doing”) and even fewer opportunities for “social learning” through direct interaction in terms of observation, feedback, or help-seeking. Some authors point out that it is still an open question of how this can be best achieved [28], and our lightweight approach does not solve this problem, either.

Similarly, implementing MML for informal workplace learning should be also lightweight from a company perspective. This is captured in two additional recommendations:

Recommendation 1 refers to an easy-to-use authoring tool: Learning managers should be able to generate learning nuggets without too much effort, as studies show that time constraints, a lack of technical skills, and inadequate infrastructure are major barriers to the implementation of digitally-supported learning activities [89]. Content types should support the instructional scheme suggested above and support mobile display. H5P allows the user to create HTML5 interactive content and publish it in learning or content management systems such as Moodle, Canvas, WordPress, or Drupal [90]. It is free and open source, appears easier to use than most commercial e-learning authoring tools, and offers many predefined interactive formats that support active learning [91]. Moreover, H5P content can be shared and reused, and open licensing is encouraged [90]. An example of MML that uses H5P to implement interactive content is [63], whereas others use authoring tools such as Articulate Storyline 360 [51] or iSpring Suite [49], or simple video recording and editing software [40][51][57].

Recommendation 2 refers to a secured platform to manage, store, and distribute learning nuggets: In most cases, developing a custom micro-learning platform will not be viable. Instead, many companies use a Learning Management Tool (LMS) with support for eLearning [92]. Most LMS support the authoring and distribution of H5P content. However, introducing and operating a fully-fledged LMS exclusively for MML might be perceived as too high an investment. This will often be the case for SMEs. As an alternative, a more lightweight Content Management System (CMS) such as WordPress seems to be sufficient: It supports H5P content generation and storage, comes with user authentication, and offers an appropriate structure to manage modular learning nuggets [68][69].

To conclude, the proposed principles and recommendations are considered effective in supporting our learners: They need short learning nuggets anchored in the work process that foster engagement in knowledge acquisition, practice, experimentation, and reflection. The low-threshold approach benefits learners in learning-deprived work contexts who may be less adept at self-directed learning. Similarly, creating and distributing learning nuggets is kept simple so that barriers to adoption are low, even for SMEs or companies with little experience with digital learning.

B. *Proof-of-Concept*

As a proof-of-concept, we use a simple website based on WordPress with an H5P plugin as a micro-learning platform. It comes with role-based authentication to protect learning nuggets against unauthorized viewing or editing. With the proof of concept, we demonstrate that implementing MML for informal workplace learning based on a lightweight approach is viable. The proof-of-concept can kick-start further refinements based on stakeholder feedback and lowers adoption barriers for institutions with limited resources to introduce MML at the workplace.

Figure 2 shows how learning managers would generate a learning nugget and attach the automatically generated QR code to a physical object in the work environment, where learners “Scan to learn” with their smartphone camera.

An exemplary learning nugget has been developed and automatically equipped with a QR code. Hereby, an H5P content type “interactive video” is wrapped into an H5P element “KewAR Code” which auto-generates a QR code linking to the readily designed learning nugget when saved. Note that to reference H5P content instead of a URL or other text content, the content type “KewAR Code” has to be extended as suggested by [71]. The H5P plugin in WordPress offers this combination of content types by default and provides comfortable authoring for such learning nuggets.

The learning nugget has been structured as suggested above, following a blueprint that allows triggering higher-order learning (see Figure 3). The example refers to using a car polishing machine in a garage. The starting point is a short video where learners see an employee operating the machine and explaining the most important do’s and don’ts, which comes close to “learning by observing”. Visual overlays to the video present key aspects, so that verbal or written text is not a main mode of presentation. The video integrates quiz questions with immediate feedback to allow learners to assess their progress. The example you see in Figure 3 is a visual true and false activity the angle at which the machine must be placed on the coating surface. Learners provide their answers by dragging the correct and the wrong options to their respective places.

A sidebar with four activity buttons was added to the video. The first refers back to the relevance of the topic. In our example, an infographic provides an aha moment, showing how expensive it can be if workers apply the polishing machine to the car at the wrong angle and cause scratches to the paint.

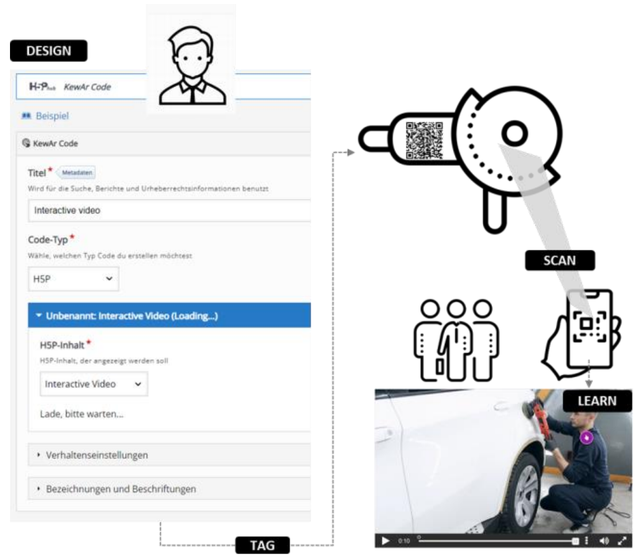

Figure 2. Scan-to-learn system

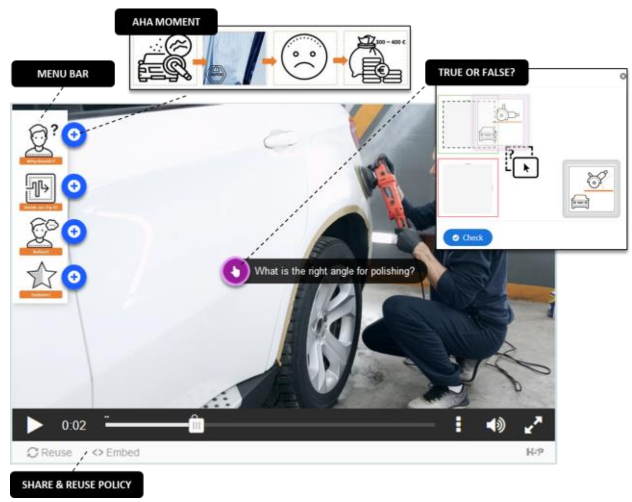

Figure 3. Example of micro-learning nugget

The second button contains ideas for practice and experimentation at the workplace. The third button offers starting points to reflect on the topic of the learning content. Workers can hit the last button to provide feedback on the learning nugget (optional). The activity buttons remain displayed throughout the video, and learners can freely decide whether and when to use them.

The exemplary learning nugget has been produced in less than one hour (excluding video recording) thanks to the existing blueprint and the user-friendly authoring tool in the H5P plugin. We are aware of the fact that commercial micro-learning platforms like EdApp [94] offer all needed functionality for our lightweight approach for handheld MML even in its cost-free version (authoring tool for interactive micro-content, automated generation of QR codes). However, as shown in [1], they come with several drawbacks (limited video upload, mandatory registration, and more click-work for learners). To conclude, our H5P-based approach for handheld MML meets the design recommendations for effective MML at the workplace at a higher level than most existing implementations described in Subsection II.C and offers improved opportunities for digitally-supported activities of informal workplace learning.

IV. Implementation Approach For Synchronous MML Based on Smart Glasses

While the suggestions discussed above in Section III are also applicable to MML with wearable devices, there are additional, specific considerations for smart glasses that warrant attention. In light of the insights gathered from Section II, we offer guidelines for both implementation approaches and technical execution aimed at promoting informal learning in the workplace through a streamlined wearable MML system.

A. *Additional Suggestions for the Design and Implementation based on Smart Glasses*

In practice, the following aspects are important to consider in advance:

- The use of smart glasses for MML must be either necessary or beneficial, such as for hands-free use, first-person perspective camera use, and/or digital overlay through the screen. Refer to the literature on smart glasses adoption for more details [76], [95].
- Reliable connectivity with other devices and the internet is essential. Consider interference from other devices, the space where the user is located, or remote areas [78], [80].
- The task should be compatible with the capabilities and limitations of the specific type of smart glasses being used. Factors to consider include battery life, open or closed screen, video/audio quality, and ease of use [83], [83].
- The cognitive demands of the task must be mapped out and weighed against the cognitive load imposed by using smart glasses [75], [77].

This means that a thorough exploration is essential between the work task, the most suitable wearable devices or type of smart glasses, as well as the anticipated acceptance by future users, to increase the likelihood of successful implementation.

B. *Proof-of-Concept*

Based on an authentic case study, we aim to demonstrate that smart glasses can be effectively utilized for the purpose of remote collaboration in a lightweight manner. There are three ways to implement this namely 1) purchasing a solution from a software developer that is tailored to the needs of the company, 2) using widely available software, and 3) building an Android-based app using open source. Two use cases in healthcare and education will be discussed below.

Figure 4. Illustrative example of smart glasses usage in wound care (shared with permission)

Use case: A patient with a complex wound requires regular visits to a hospital specialist and receives at-home nursing care for wound management. By integrating smart glasses into the home-care regimen, a connection can be established with a remote medical expert located at the hospital.

This allows the expert to evaluate the wound remotely, instruct the community nurse on specific treatments, and ultimately save both the patient (and their caregiver) a trip to the hospital. Additionally, it saves time for the hospital-based expert and provides a direct learning experience for the community nurse [36]. See Figure 4 for an illustrative example using Google Glass. As a proof-of-concept, the Vuzix M400 smart glasses were used in practice instead of Google Glass due to EU regulations. Furthermore, in the use case in wound care, additional software from an external provider was used because of the ease of use. In another use case involving remote assessments of students, Microsoft Teams was utilized.

Another example of this use case also involves Android-supported smart glasses like the Vuzix M400. On this platform, applications can be manually installed as discussed in Section II. With that software, in addition to video broadcasting, it is also possible to selectively share data: for example, drawings on a captured photo or forms. Software for remote expert viewing can be acquired from partners selling smart glasses or through platforms like Microsoft Teams. The rapid and increasing implementation of Microsoft Teams since the COVID-19 pandemic has demonstrated its capability for hosting virtual meetings or broadcasting live video streams [96].

V. Discussion And Conclusions

In the future, we need even more informal learning to support a tremendous level of workforce upskilling as we face major transformation processes related to climate change, population aging, as well as ongoing digitization and automation. However, many jobs offer limited opportunities for informal learning, in particular, if human-human interaction is scarce, access to stationary desktop computers is difficult, and workers are less experienced in self-directed learning.

In Section II, we have shown that the concept of MML closely overlaps with the characteristics of informal learning. Variations of MML (hand-held vs. hands-free and synchronous vs. asynchronous) have been described suggesting the MML matrix as a novel classification approach.

To conclude, Table II evaluates how much informal workplace learning can be enhanced by two common types of MML that we studied in detail: classical handheld MML and mobile micro-interactions (MMI) using smart glasses as an example of wearable devices. For handheld MML, we additionally differentiate between current implementations (column 1), and our novel lightweight approach based on open-source technologies and an H5P instructional blueprint following the design recommendations for MML (column 2).

Best practices analyzed (Section II.C) have shown that MML based on handheld devices and following an asynchronous approach without a trainer is the most broadly used approach to offer mobile micro-learning nuggets at the workplace.

The proof-of-concept for handheld MML in Subsection III shows that based on a lightweight approach using a website with a simple CMS system, H5P interactive technology, and QR codes, the design and distribution of short but engaging MML nuggets are achievable even for novices in the field of micro-learning and SMEs with limited resources for workforce training. Our novel approach reduces the effort needed for content creation – often perceived as time-consuming and cumbersome – to a minimum (see also [1]).

Good practices to overcome the pitfalls of existing implementations of handheld MML (see Subsection II.C) are: Using short videos as a basis, placing visuals and animations over "verbals", designing stand-alone learning nuggets for self-directed learning with integrated quizzes and other activities that foster experimentation and reflection.

TABLE II. MML TYPES AND POTENTIAL FOR INFORMAL LEARNING

Criteria	***handheld MML***	***handheld-MML (H5P)***	***MMI (hands-free)***
	(1)	***(2)***	***(3)***
Self-directing learning activities	●	●●	●●
Forms of higher-order learning	●	●●	●●●
Learning units situated in work process	●	●●	●●●
Media formats and instructional strategies suited for learning-deprieved settings	●	●●	●●
Lightweight implementation (suited for SMEs)	●●	●●●	●
Overall potential for informal workplace learning	6	11	11

Legend: ● some potential ●● medium potential ●●● high potential for informal workplace learning with respect to the criteria evaluated

To sum up, the improved approach to handheld MML based on an H5P-based instructional blueprint fosters the effectiveness of MML for informal workplace learning concerning all the criteria evaluated in Table II. Still, keep in mind that the anytime-anyplace nature restricts the opportunities for the social part of learning at the workplace (see also Section III.a).

The use case presented in Subsection IV depicts how smart glasses as an example of assisted reality wearables allow to smoothly offer hands-free synchronous learning based on micro-interactions (MMI) with experts, without interrupting learners' manual work. Using wearables to bring learning content to the learner tremendously improves the degree learning units are situated in actual work routines as compared to classical handheld.

MML. Moreover, higher-order learning based on practice and experimentation may be fostered when a remote expert guides the learner step-by-step through the respective work routine and provides real-time feedback. Albeit at a distance, MMI even provides some opportunities for social learning. As the main communication modes are verbal and visual when implementing MMI based on smart glasses, access for learners with restricted reading comprehension is somewhat improved as compared to current implementations of handheld MML where understanding written text is often more important. Still, synchronous MMI highly relies on verbal communication which imposes learning barriers for those with limited linguistic abilities.

A major drawback so far for using wearables such as smart glasses for MML at the workplace is however, that it is a rather complex technology, which often pushes back small companies with a high share of blue-collar workers or other occupations outside classical office spaces. Moreover, smart glasses are still in an early phase of diffusion and are currently mainly used for synchronous MMI. This necessitates the involvement of a remote expert. If the expert is from within the company, this can be managed through remote work. However, consulting an external expert is often too costly for small businesses. Asynchronous, hands-free MML where learners can access learning snippets on-demand without interrupting their manual work processes are still rare in publications to date. The reader may object that smart glasses are broadly used for augmenting real work settings with additional information based on AR and VR technologies. We consciously have abstained from including this approach in our paper as authoring AR and VR content demands high investment in terms of time, competency, and money that in most cases, small companies are not able to cover.

In conclusion, both methods discussed in this paper - the enhanced handheld MML approach and the hands-free MMI approach - perform similarly well in promoting informal workplace learning. Table II overview shows that these two methods have complementary strengths and weaknesses. An encouraging avenue for future research could be to combine them: Creating an evidence-based, reusable digital blueprint using interactive, open-source technologies like H5P and adapting them for smart glasses as a hands-free delivery method.

In a broader sense, each of these two feasible methods, when considered individually, still requires further in-depth research, especially in terms of learning outcomes and applying the training to real-world settings with non-academic learners, instead of relying solely on evidence from academic educational environments. Therefore, we recommend generating and implementing more use cases for the improved handheld MML approach and MMI with smart glasses in a real-world context, with a focus on making the implementation easier and reducing barriers to learning in environments that may not yet have ideal informal learning conditions. Knowledge and practical experience in this area are crucial for taking the next steps and are relevant for researchers, small and medium-sized enterprises, practitioners, and other stakeholders in knowledge transfer.

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