Mastery versus self-directed blended learning in Basic Life

Support: a randomized controlled trial

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ABSTRACT

Background: Blended learning combines online learning with face-to-face learning. Research investigating the effect of different blended learning models to teach Basic Life Support (BLS) is lacking.

Objectives: To investigate the effect of a mastery learning (ML) versus a self-directed learning (SDL) blend on students' BLS performance. In ML, students learn BLS as a linear sequence meaning each step should be 'mastered' prior to advancing to the next. In SDL, students' autonomy is increased for his or her learning trajectory leading to non-linear, user driven learning paths.

Methods: A randomized controlled trial. Four conditions were created by combining two learning models (SDL and ML) in two learning phases (online and face to face). Bachelor students (n = 145) were randomized over these four conditions. In all blends an online learning module was available for one week prior to a face-to-face learning component of which the duration was 45 minutes. All learners' BLS performance was assessed individually and unannounced one week following blended learning. An individual BLS score was calculated combining cardiopulmonary resuscitation (CPR) variables reported by a Laerdal ResusciAnne Manikin and qualitative observations by two trained researchers.

Results: Students' CPR performance adhered to international 2015 guidelines for all groups. Median BLS-performance was 83.0% (interquartile range 13.2%). No statistical differences between groups were found for BLS performance or CPR variables.

Conclusion: All blended learning models were highly time-effective since the face-to-face component only took 45 minutes and learning outcomes adhered to guidelines.

45 Key words: education, training, Cardiopulmonary Resuscitation, Basic Life Support

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INTRODUCTION

Sudden cardiac arrest is a major cause of death across Europe. Each year it occurs in 0.5 to 1.0 per 1000 inhabitants. The average survival to hospital discharge after out-of-hospital cardiac arrest is less than eight percent [1]. Increasing this survival rate relies not only on medical science but also on educational efficiency [2]. Umbrella organizations responsible for resuscitation guidelines such as The American Heart Association (AHA) and The European Resuscitation Council (ERC) appear to be evolving in their educational strategy as more 'blended learning' methods become available [2]. Blended learning combines asynchronous internet technology or 'e-learning' with face-to-face learning [3]. Implementing a blended learning approach to teach lifesaving skills should even be encouraged according to some national resuscitation councils [4]. The rationale for this recommendation is found in studies showing the potential of blended learning to reduce costs while maintaining similar learning outcomes [5]. Research by Perkins et al. showed that a blended approach for advanced life support (ALS) training led to a slightly lower pass rate for cardiac arrest simulation tests but similar scores on a knowledge test when compared to conventional ALS training. Also, the cost per participant of the blended training was less than half of the cost for the conventional training [6]. In a large-scale study comparing a blended learning course to a conventional face-to-face course for ALS training results showed equivalent learning outcomes with added value found in benefits as candidate autonomy, cost-effectiveness, decreased instructor burden and improved standardization of course material [4]. Although blended learning seems a promising strategy to teach and learn BLS, it is unclear how these blended learning courses should be designed to maximize their effectiveness. The design of blended learning courses as well as their scientific underpinning are very often vaguely

described in the methods section of research papers [4, 5, 6]. In addition, educational studies to date have not introduced the design of blended learning as an independent variable for learning BLS. This study implemented two blended learning models for BLS namely Mastery Learning (ML) and Self-Directed Learning (SDL).

Mastery learning refers to a category of instructional models with common characteristics in timing, organization and resources to ensure that most students are able to reach a certain criterion level of performance. A distinctive aspect of ML is that instruction is provided in a hierarchical, linear sequence meaning that each student should 'master' a certain step prior to advancing to the next [7]. This concept of learning a behavior by learning a linear sequence of less complex components is rooted in Skinners Programmed Instruction format [8]. Previous research showed ML to be effective in education of medical professionals [9] [10]. In their guidelines for cardiopulmonary resuscitation and emergency cardiovascular care the AHA states there is substantial evidence to suggest that ML is the key to skill retention and the prevention of rapid decay in skills and knowledge after simulation-based learning [11]. They do point out that although the idea behind ML is to ensure all learners reach a certain standard of performance, the time required to do so may vary [11]. One study on BLS training in laypeople showed ML to be effective but no major benefit was found compared to a time-based BLS course [12].

A different strategy can be found in the concept of self-directed learning (SDL). SDL has been widely investigated in educational settings and has proved to be effective for teaching (psycho)motor skills [13]. Although often used in medical education aiming to reach a variety of goals (acquiring biomedical knowledge and skills, patient-physician relationships, communication) the term SDL has not always been clearly defined [14]. A common aspect in the different uses of SDL is increased control of the

learner in his or her learning process which leads to non-linear, user driven learning paths. The possibility for personalization of learning experiences by giving learners control in their own learning process could lead to a 'tailored learning experience' resulting into better learning outcomes. Previous studies showed forms of SDL being effective to improve competence in cardiopulmonary resuscitation (CPR) [15].

This study wants to add to the literature on blended learning in CPR education by using the blend as independent variable. We aimed to map the learners' use of an online module when using a blend where face-to-face time is limited to 45 minutes and to investigate the effect of ML versus SDL on BLS performance of bachelor students.

MATERIALS AND METHODS

Participants and setting

Participants in this study were 145 Bachelor students (81 females, 64 males, average age = 20) in teacher education. Participants were told they would learn BLS using a blended learning approach but were unaware that different instructional models would be used. Students with prior BLS training were excluded from participation in the study. The study was approved by the first author's university and informed consent was received from all participants.

Study intervention and procedures

All 145 subjects were taught BLS using a blended learning trajectory which consisted of two learning phases: (1) an online training, and (2) a face-to-face, instructor-led training (see figure 1). All students were randomized over two face-to-face conditions (ML or SDL). Within each face-to-face condition students were randomized to one of two online conditions (ML or SDL) controlling for gender. All randomizations were

conducted using an online random number generator (www.randomizer.org). Through the development of two different learning models for two learning episodes four experimental groups were created (see figure 1).

For all participants the first learning phase consisted of an online learning program. Students were given access to this program one week prior to the face-to-face training using the learning management system (LMS) of their university. Each online learning program consisted out of two parts: a 'learning part' and an 'assessment part'. The learning part contained video clips of all BLS-actions to be performed as prescribed by international guidelines. The assessment part contained questions testing the knowledge of the user. All participants were told they were expected to learn BLS using the online learning program at any time or place prior to the face-to-face training and that they could retake the assessment part as many times as they wanted. Participants were briefed that the instructor would check the LMS to see if they opened the learning program and completed the online assessment prior to the workshop. Students were however aware that BLS training was not a formal part of their curriculum and their learning results regarding this skill would not impact their academic results.

During the face-to-face workshop all students learned BLS using a reciprocal learning strategy meaning they worked in pairs to maximize each other's learning with iPads. This learning model has shown to be effective in BLS training [16] [17] [18]. In reciprocal learning students alternate between assuming a role as 'doer' and a role as 'helper'. Each pair had one manikin and one iPad available. The iPad was running an application specifically designed to learn BLS in a reciprocal learning strategy that showed to be effective in previous research [19].

Enter figure 1 near here

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148 Independent variable: blended learning model

149 The independent variable in this study was the blended learning model. Combining
150 both ML and SDL in the online and/or face-to-face learning episode led to the creation
151 of four experimental groups (see figure 1).

152 Online learning in the ML condition meant that students had to complete a certain step
153 before advancing to the next. In the learning part of the online ML-program video clips
154 of the BLS-procedure could only be consulted in the correct sequence as prescribed
155 by ERC-guidelines. During the online assessment students could not advance to the
156 next question without providing a correct answer. Feedback was provided after each
157 correct or incorrect answer. Students could not skip questions, but they were allowed
158 to navigate back to the training module to acquire the information needed to provide a
159 correct answer. A student completed the online ML-program when all questions were
160 answered correctly.

161 Online learning in the SDL conditions meant that students had more control over
162 navigation compared to the ML conditions. In the learning part of the online SDL-
163 program video clips of the BLS procedure could be consulted in a self-chosen
164 sequence. During the online assessment students could navigate freely through the
165 questions choosing to answer or skip them. Each time an answer was given feedback
166 was provided. Students could navigate back to the specific part of the learning module
167 containing the information needed to answer the question. At the end of the
168 assessment students were given a score according to the number of correct, skipped
169 or wrong answers. This score was reported in the LMS system along with the SDL-
170 group average.

171 The face-to-face ML-training and SDL-training had a standardized basic structure. All

face-to-face workshops followed the same basic structure: after a five-minute introduction by the workshop leader students worked in pairs for 40 minutes using a reciprocal learning strategy. In the ML-training the student pairs started by learning the first step of BLS before advancing to the second, then the third and so on. The instructor was in charge of the progress through the steps. Students switched roles after they completed the protocol. In the SDL-training students could choose the sequence in which they learned BLS and alternated between the role of the helper and the role of doer every five minutes.

Assessment of BLS performance

Performance was measured unannounced one week after the face-to-face training. All assessments were individually completed on a Laerdal AED Resusci Anne manikin connected to a laptop running the Laerdal PC-Skill Reporting system version 2.21 (Laerdal Medical, Vilvoorde, Belgium). All assessments were videotaped. Each assessment started with a standardized instruction in which participants were asked to perform the entire BLS procedure and were stopped by the assessor after three cycles of chest compression and ventilation. Table 1 provides an overview of the CPR variables recorded by the mannequin. Based on the video tapes a qualitative assessment was made by two independent trained observers who were blinded to the experimental conditions evaluating the following variables: safe approach, check responsiveness by shaking gently and shouting loudly, shout for help, opening airway, check for breathing, call 112, continuation of CPR, performed all BLS skills and performed all BLS skills in correct sequence. The variable 'continuation of CPR' was assessed by asking participants how long they would continue performing CPR. The online training module and the application running on the iPads during the face-to-face

workshop instructed them to continue until qualified help arrives, until the victim breathes normally or until you become exhausted. The collected CPR data from the mannequin and the observational data were entered in a scoring system based on the Cardiff test [20]. Modified Cardif scales have been used in research to assess BLS performance [18]. Total BLS scores ranged between 18 (i.e., 0%) and 73 (i.e., 100%) points.

Intervention fidelity

All lessons were led by the same male instructor (age 30) with eight years of teaching experience in a teacher education program. He was also a certified BLS instructor. All lessons had a standardized protocol and were observed by a member of the research team. No breaches of protocol were reported. The workshop leader was responsible for timekeeping, which was standardized in both settings. No violation of this standardization was reported.

Data Analysis

Statistical package for the social sciences (SPSS), version 22. was used to conduct statistical analysis. Shapiro-Wilk testing showed that total BLS scores and eight out of ten CPR variables were not normally distributed therefore Kruskal-Wallis testing was used to compare BLS scores and CPR values between groups. Significance level was set at .05. It was calculated that to detect a difference in BLS score of 10%, with a standard deviation of 10%, a power of .80, and a p-level of .05 we would need 27 students in each arm of the study.

RESULTS

In total 127 students (72 female, 55 male) completed the assessment one week after being taught BLS using a blended learning strategy. Students who failed to open the online assessment or attend the face-to-face training were excluded from this study. Interrater reliability for video observations was measured using Cohen's Kappa and resulted in .81 based on 33% of the total sample. Flow of participants is shown in figure 1.

Students' use of the online module

Data from the LMS showed that 131 out of 145 students completed the online training episode and the number of times they opened it. Mann-Whitney U test did not show a significant difference for the amount of times the online program was opened by students in the online SDL-condition (Mdn = 2) versus the ML-condition (Mdn = 1), $p=.068$.

Students' CPR and BLS performance

Median and interquartile range for CPR variables can be found in table 1. No significant differences between groups were found.

Enter Table 1 near here

A comparison of BLS scores converted to percentages between groups can be found in graph 1. Total BLS scores were not significantly different between groups.

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DISCUSSION

The aim of this study was to map the online behavior when using a blend where face-to-face time is limited to 45 minutes and to investigate how the design of a blended BLS-course based on two learning models (ML and SDL) models affects learning outcomes. We argue this type of research is currently lacking and is essential to fully reach the potential of blended learning in medical training.

In this study, 90% of all students opened the online BLS module. To our knowledge, previous BLS studies in blended learning have not reported data on this variable. The fact that the majority of students opened the online module is an important finding given the relatively low student accountability. Task accountability refers to the evaluation of student behavior and the communication of that evaluation to the student [21]. This evaluation can be informal such as praise or verbally correcting an error, or more formal in terms of an examination grade. There is substantial evidence demonstrating the mediating role of accountability systems on student learning [22]. In this study, task accountability for opening the online module consisted of the teacher 'expecting the students to open this module prior to the face-to-face session'. However, since no consequences followed when students performed or failed to perform this behavior, accountability was low. Also, although the online module contained an assessment part, no goals were communicated in terms of the expected quality of that assessment (i.e., pass or fail criteria). Research has consistently shown that students only treat tasks seriously for which they are held accountable [21]. Future research in blended learning should therefore investigate accountability structures for the online modules and report on those in the methods section of research papers.

The use of blended learning as presented in this work showed to be an effective teaching method for BLS. For all groups CPR- and BLS-performances adhere to

international guidelines. In addition, an overall median BLS score of 83% is surprisingly high when compared to other research using similar scales for BLS assessment on similar test populations [17]. For example, previous research with university students found average scores for different learning conditions ranging from 77% to 81% [17]. Two aspects make this average level of performance remarkable: the limitation of face-to-face time of 45 minutes and the fact that BLS was not a mandatory part of the curriculum meaning BLS performance did not contribute to students' grade at school. Many educational studies in BLS use study samples in which BLS is a mandatory subject and performance is tied to evaluation scores, which creates a higher level of accountability with students. Interpreting research outcomes with this consideration in mind might lead to more finetuned recommendations. We suspect these high scores arose because of the two learning phases (online and face to face), the sequence in which they were presented and the fact that when designing the blends for this study all conditions were based on a combination of well-established learning models (ML and SDL). Although the blends used in this research showed fundamental differences, the combination of these blends with the learning task (BLS) and the learning time (two weeks) seemed to produce near identical learning outcomes. The fact that no differences were found between groups based on learning models could be explained by one or more of the following reasons. First of all, the height of this median test score confirms previous research demonstrating the effectiveness of both ML and SDL as learning model for BLS education and may level out intergroup differences because of a ceiling effect. In addition, the nature of the learned skill might also play a role in these results. BLS consists of seven straightforward steps to be executed in one fixed sequence as prescribed by international guidelines. Other, more complex skills may produce different learning outcomes related to blend design. Similar to findings in this

study previous research hypothesized ML to produce superior learning outcomes for BLS training in laypeople but could not confirm this [12]. Learning time may also play an important role as a review by Cook et al. concludes ML seems to be superior as learning model in education for healthcare professionals using simulation but takes more time [10]. It has been suggested that 21st century educational strategies with straight forward learning outcomes such as BLS require a high frequency of short training sessions to gain mastery of the skill. As such, effective online modules in blended learning might serve as refresher sessions to maintain performance level over time.

Limitations

All subjects in this study were bachelor level students which limits generalization of findings to other groups. Sample size did not allow to divide subjects over all four conditions at class level.

Conclusion

Blended learning proved to be a highly effective teaching method for BLS regardless of the learning model the blend was based on. In this case the use of ML and SDL led to similar use of an online module and equal learning outcomes after completing the blend. Despite the limited face-to-face time of 45 minutes and the low accountability of students, the learning outcomes adhered to international guidelines.

Further research is needed to investigate the effect of different blended learning models in other educational settings and their populations. This research should focus on the teaching and learning of skills with different levels of complexity, the learning time available and the accountability of learners.

321 **REFERENCES**

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- [1] Bossaert LL, Perkins GD, Askitopoulou H, Raffay VI, Greif R, Haywood KL, et al. European Resuscitation Council Guidelines for Resuscitation 2015 Section 11. The ethics of resuscitation and end-of-life decisions. *Resuscitation* 2015; 95:302-311.
- [2] Søreide E, Morrison L, Hillman K, Monsieurs K, Sunde K, Zideman D, et al. The formula for survival in resuscitation. *Resuscitation* 2013; 84:1487-1493.
- [3] Garrison R, Kanuka H. Blended learning: Uncovering its transformative potential in higher education. *Internet and Higher Education* 2004; 7:95-105.
- [4] Thorne C, Lockey A, Bullock I, Hampshire S, Begum-Ali S, Perkins G. E-learning in advanced life support: an evaluation by the Resuscitation Council (UK). *Resuscitation* 2015; 90:79-84.
- [5] Lockey A, Dyal L, Kimani P, Lam J, Bullock I, Buck D, et al. Electronic learning in advanced resuscitation training: The perspective of the candidate. *Resuscitation* 2015; 97:48-54.
- [6] Perkins GD, Kimani PK, Bullock I, Clutton-Brock T, Davies RP, Gale M, et al. Improving the efficiency of advanced life support training: a randomized, controlled trial. *Annals of Internal Medicine* 2012; 157:19-28.
- [7] Slavin RE. Mastery Learning Reconsidered. *Review of Educational Research* 1987; 57:175-213.
- [8] Skinner BF. Teaching Machines. *Science* 1958; 128:968-977.

- [9] Mcgaghie W. Mastery Learning: It Is Time for Medical Education to Join the 21st Century. *Academic Medicine* 2015; 90:1438-1441.
- [10] Cook DA, Brydges R, Zendejas B, Hamstra SJ, Hatala R. Mastery Learning for Health Professionals Using Technology-Enhanced Simulation: A Systematic Review and Meta-Analysis. *Academic Medicine* 2013; 88:1178-1186.
- [11] Web-based Integrated 2010 & 2015 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care, <https://eccguidelines.heart.org/wp-content/themes/eccstaging/dompdf-master/pdf/files/part-14-education.pdf>. Accessed august 21st 2018.
- [12] Boet S, Bould DM, Pigford AA, Rössler B, Nambyiah P, Li Q, et al. Retention of Basic Life Support in Laypeople: Mastery Learning vs. Time-based Education. *Prehospital Emergency Care* 2017; 21:362-377.
- [13] Byra M, Teaching styles and inclusive pedagogies., in *Handbook of Physical Education*, 2006, pp. 449-466.
- [14] Ainoda N, Onishi H, Yasuda Y. Definitions and Goals of "Self-directed Learning" in Contemporary Medical Education Literature. *Ann Acad Med Singapore* 2005; 34:515-524.
- [15] Cason C, Kardon-Edgren S, Cazzell M, Behan D, Mancini M. Innovations in basic life support education for healthcare providers: improving competence in cardiopulmonary resuscitation through self-directed learning. *Journal for Nurses in Staff Development* 2009; 25:E1-E13.

- [16] Iserbyt P, Byra M. The design of instructional tools affects secondary school students' learning of cardiopulmonary resuscitation (CPR) in reciprocal peer learning: a randomized controlled trial. *Resuscitation* 2013; 84:1591-1596.
- [17] Iserbyt P, Mols L, Charlier N, De Meester S. Reciprocal Learning with Task Cards for Teaching Basic Life Support (BLS): Investigating Effectiveness and the Effect of Instructor Expertise on Learning Outcomes. A Randomized Controlled Trial. *Journal of Emergency Medicine* 2014; 46:85-94.
- [18] Iserbyt P, Elen J, Behets D. Peer evaluation in reciprocal learning with task cards for acquiring Basic Life Support (BLS). *Resuscitation* 2009; 80:1394-1402.
- [19] Iserbyt P. The effect of Basic Life Support (BLS) education on secondary school students' willingness to and reasons not to perform BLS in real life. *Acta Cardiologica* 2016, 71:519-526.
- [20] Whitfield R, Newcombe, R Woollard M. Reliability of the Cardiff Test of basic life support and automated external defibrillation version 3.1. *Resuscitation* 2003; 59:291-314.
- [21] Doyle W. Academic Work. *Review of Educational Research* 1983; 53:159-199.
- [22] Hastie P, Siedentop D. An Ecological Perspective on Physical Education. *European physical education review*, 1999 5:9-29.

ILLUSTRATIONS

Figure 1: Grouping and flow of participants. Drop out in week 1 means participants did not open online training. Drop out in week 2 means participants did not attend face-to-face training.

		Group 1 n = 35	Group 2 n = 31	Group 3 n = 32	Group 4 n = 29
	Guideline	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)	Mdn (IQR)
Total compressions performed	90	91 (3)	90 (1)	91 (5)	90 (2)
Chest compression rate (min-1)	100	102 (17)	98 (14)	102 (22)	96 (26)
Chest compression depth (mm)	40-50	56 (8)	51 (10)	55 (8)	54 (14)
Chest compressions with correct hand placement (%)	N/A	87 (85)	65 (56)	78 (84)	83 (37)
Correct chest compressions	N/A	37 (83)	19 (51)	40 (77)	57 (78)
Duty cycle (%)	50	41 (6)	41 (7)	43 (12)	38 (10)
Total rescue breathing performed	6	6 (5)	5 (4)	6 (4)	5 (4)
Rescue breathing volume (mL)	500-600	462 (407)	358 (142)	434 (273)	356 (249)
Rescue breathing flow rate (mL/s)	500-600	298 (573)	169 (183)	232 (377)	190 (450)
Correct rescue breathing	N/A	1 (2)	0 (1)	1 (2)	0 (1)

Table 1: Comparison of median and interquartile range (IQR) for CPR variables after three compression: ventilation cycles between conditions based on design of blend

Figure 2: Comparison of BLS scores between conditions based on design of blend

340 **ARTICLE SUMMARY**

341 1) Why is this topic important?

342 Blended learning is increasingly used as an educational strategy to teach Basic Life
343 Support (BLS). Research on how the design of a blend affects learning outcomes is
344 lacking.

345 2) What does this study attempt to show?

346 The aim of this study was to investigate how the design of a blended BLS-course
347 based on two learning models (mastery learning and self-directed learning) models
348 affects learning outcomes.

349 3) What are the key findings?

350 The use of blended learning as presented in this work showed to be a highly effective
351 teaching method for BLS as for all groups CPR- and BLS-performances adhere to
352 international guidelines despite limited face-to-face time and limited student
353 accountability. No differences were found between different blends.

354 4) How is patient care impacted?

355 Out of hospital cardiac arrest survival depends on effective BLS education in
356 laypeople. The development of high quality educational methods is of prime
357 importance to increase the amount of people who are able to perform this lifesaving
358 skill effectively in case of sudden cardiac arrest. This work presents a blended
359 learning approach and its scientific underpinning producing strong learning outcomes
360 in a time-effective manner.