The Flipped Classroom Approach to Improve Fundus Examination Skills for Medical Students: a Mixed-methods Study

Kiyoshi Shikino (✉ kshikino@gmail.com)
Chiba University Hospital
Claudia A Rosu
MGH Institute of Health Professions
Daiki Yokokawa
Chiba University Hospital
Shingo Suzuki
Chiba Medical Center
Yusuke Hirota
Tokyo Medical University Hachioji Medical Center
Katsumi Nishiya
Kansai Medical University
Masatomi Ikusaka
Chiba University Hospital

Research Article

Keywords: bloom's taxonomy, flipped classroom, funduscopic examination, physical examination

Posted Date: January 23rd, 2021

DOI: https://doi.org/10.21203/rs.3.rs-149019/v1

Version of Record: A version of this preprint was published at BMC Medical Education on August 13th, 2021. See the published version at https://doi.org/10.1186/s12909-021-02857-8.

Abstract

BACKGROUND: Training for the fundus examination using traditional teaching is challenging, resulting in low generalist physicians' confidence in performing the funduscopic exam. At the same time, there is growing evidence suggesting flipped classrooms' value in teaching physical examination procedures. However, whether the flipped classroom is superior to the traditional, lecture-based teaching for the funduscopic exam and the cognitive processes supporting its effectiveness has not yet been determined.

METHODS: We conducted a sequential explanatory mixed-method study to compare the flipped classroom approach's effectiveness versus the traditional lecture-based classroom for teaching the funduscopic exam to the medical students at Chiba University in Japan. Medical students were randomly assigned to either a flipped classroom group or a traditional teaching group. We then quantitatively measured the diagnostic accuracy of funduscopic findings, the length of time to perform the fundus examination, and students' confidence in performing funduscopic examinations, before and after attending the specific classrooms. Next, we conducted student focus groups to explore the students' thinking processes in the flipped classroom and traditional teaching of fundus examination, respectively. The qualitative data were analyzed using the qualitative content analysis method.

RESULTS: Diagnostic accuracy was significantly higher using the flipped classroom method (flipped: 36.6% to 63.4%, traditional: 28.3% to 34.6%, $F(1,310) = 11.0$, $p = .001$). The total examination time was significantly shorter using the flipped classroom teaching (flipped: 85.4s to 66.9s, traditional: 85.3s to 76.3s, $F(1,310) = 14.7$, $p < .001$). Six semi-structured focused group interviews were conducted (n=36). In the flipped classroom group, we identified 12 categories corresponding to five levels of the revised Bloom's taxonomy: remember, understand, apply, analyze, evaluate. Five categories were identified in the traditional classroom group corresponding only to three levels of the revised Bloom's taxonomy: understand, apply, analyze. Interrater reliability was substantial (Cohen's kappa = 0.81).

CONCLUSIONS: Teaching medical students funduscopic examination using the flipped classroom methodology leads to improved diagnostic accuracy, confidence, and motivation for funduscopic examinations, while reducing total examination time. The flipped classroom teaching method enabled higher levels of cognitive activity than the traditional, lecture-based classroom, as assessed using the revised Bloom's taxonomy.

Introduction

All generalist physicians must be proficient in the funduscopic examination for detecting prevalent eye diseases such as diabetic retinopathy, hypertensive retinopathy, papilledema, and retinal hemorrhage.[1,2] The funduscopic exam is taught to medical students and medical interns, who are expected to obtain the skills necessary to perform it.[3] However, previously published literature shows that training for the fundus examination using traditional teaching methods – where the teacher is typically the central focus of lectures and the primary dissemination of knowledge takes place by attending the lectures – is difficult. This results in reduced of confidence on the part of generalist physicians in performing this examination.[4–11] In Japan, one study found out that only 80% of medical interns and attending physicians conducted fundoscopic exams only every 2–3 months, even for patients who needed more often them as per current guidelines.[7]

A possible solution for this situation could be applying novel methods to teach the funduscopic exam, like the flipped classroom. The flipped classroom is a learner-centered approach to teaching where the traditional classroom and self-study activities are reversed or "flipped."[12–14] The course's materials – reading materials, video lectures, quizzes –are presented to the learners before attending in-person activities in the classroom and emphasize the lower levels of learning objectives of Bloom's taxonomy.[15,16] The classroom's physical and temporal space is reserved so the students can apply, analyze, and evaluate (higher-order levels of learning objectives of the Bloom's taxonomy) the newly learned material via in-person activities facilitated by faculty and by collaboration with their peers.[17,18] The active learning and differentiated instruction that the flipped classroom approach promotes makes it effective in optimizing the use of live teaching time.[19] This results in a positive effect over the traditional teaching with respect to Bloom's higher order thinking and problem-solving skills.[20–22] Flipped classroom yields a significant improvement in health professions education students' learning, too, when compared with the traditional teaching methods.[23]

Additionally, there is some evidence suggesting the usefulness of flipped classrooms in teaching physical examination procedures.[24] When incorporating a flipped classroom model into teaching point-of-care ultrasound (POCUS) to the 1st year medical students, the students demonstrated proper use of the ultrasound machine functions and basic competency in performance and interpretation of POCUS.[24] However, little is known about the usefulness of flipped classroom in teaching funduscopic examination to medical students.

The purpose of this mixed methods sequential explanatory study was to compare the effectiveness of the flipped classroom approach versus the traditional lecture-based one for teaching the funduscopic exam to the 5th grade medical students at the Chiba University in Chiba, Japan by assessing the diagnostic accuracy of funduscopic findings (i.e., normal fundus, optic disc edema, pathological optic disc cupping, or not observed) and time taken to identify funduscopic findings for students in the flipped classroom vs the students in the traditional classroom. Furthermore, we also assessed the changes in confidence and motivation to perform the funduscopic exam for the students in the two groups, via a self-administered questionnaire. We followed these with a qualitative content analysis of data obtained from focus groups conducted with a selected sample of the students participating in the quantitative arm of the study, to help explain and elaborate on the quantitative results.

Methods

Study Design

Using a pragmatic approach, we employed a mixed method design that incorporated both quantitative (questionnaires) and qualitative (focus groups) techniques.[25–27] This type of research study design capitalizes on the strengths of both quantitative and qualitative data, while minimizing the shortcoming of each methodology. Furthermore, it allows the researchers to better understand the experimental results, while incorporating the participants; perspectives. The National Institutes of Health advises a mixed method approach to research "to improve the quality and scientific power of data" and to better address the complexity of issues facing the health sciences today, including the health professions education.[28,29] The initial, quantitative arm of this study included a randomized controlled trial to test the effect of the teaching method on students skill acquisition and confidence and motivation in performing the fundoscopic exam. The qualitative data – medical students perceptions were collected after the preliminary didactics experiment because we assumed that quantitative research alone could not sufficiently capture the thinking processes of the study participants, that seems to influence the effectiveness of the flipped classroom approach for improving learning.[30] We then compared the revised Bloom's taxonomy levels of knowledge attained by the two groups.

Subjects

A randomized experimental design was used to compare the effects of the two practical guidance methods (flipped classroom vs traditional method) on student performance on the fundoscopic examination. The study population consisted of 104 Chiba University medical students participating in a general medicine clerkship rotation from 2018 to 2019. All 104 medical students signed an informed consent prior to enrolling in our study. Participation was voluntary and did not impact the students' academic standing in any way.

None of the participants had a prior clinical clerkship rotation in ophthalmology. Participants were randomly assigned to either the flipped classroom groups (intervention group: n = 51) or the traditional teaching groups (control group: n = 53)

Procedure

The outline of the study design is presented in Fig. 1. Before starting the funduscopic training, all participants examined the eye fundus on a simulator (EYE Examination Simulator®; Kyoto Kagaku Co, Kyoto, Japan) using a PanOptic ophthalmoscope (pretest). Each participant was assigned 3 cases and observed 1 eye for 90 seconds. They presented their findings thereafter and presented their findings (3 findings each).

The students in the flipped classroom groups watched a 10-minute e-learning video on fundus examination skills. They were also able to watch the video repeatedly on their smartphone, tablet, and PC. Students in the traditional teaching group, attended a lecture with a similar content as the video. In both the video and the lecture, the faculty instructed the students in each group about their grip, posture, procedure, angle, and light intensity and taught fundus examination skills using the iExaminer system while sharing screens with students. The iExaminer system consists of three core components: the PanOptic ophthalmoscope, the iExaminer adapter, and the iExaminer application.[31] The PanOptic ophthalmoscope addresses the fundamental challenge in ophthalmoscopy – to get a good view of the fundus in order to make a sufficient assessment. Patented Axial PointSource™ Optics make it easy to enter undilated pupils, offering a 25º field of view, resulting in a view of the fundus "that's 5X greater than you see with a standard ophthalmoscope in an undilated eye. Direct viewing of the fundus through the PanOptic provides better images of the retinal changes caused by hypertension, diabetic retinopathy, glaucoma, and papilledema to enable clinicians to make these diagnoses earlier. The iExaminer adapter is designed to attach the PanOptic ophthalmoscope to the iPhone and the iExaminer app gives the users the ability to take, store, retrieve and send fundus images right on their iPhone. It also allows medical students and their teacher to share the same visual perspective. All instruction time was standardized to 30 minutes. Three different teachers were randomly assigned to each session. The teachers were previously trained using the same instructional guide (developed by KS, SS, and YH) in order to minimize the individual variability in guiding the students.

After completing their specific training sessions, all the study participants examined the eye fundus again (posttest) on the EYE Examination Simulator® using a PanOptic ophthalmoscope. Each participant was assigned 3 cases and observed 1 eye for 90 seconds. They presented their findings thereafter.

This study followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guideline, and the flow diagram is available (Supplement 1).

Main outcome measures

The diagnostic accuracy of funduscopic findings (i.e., normal fundus, optic disc edema, pathological optic disc cupping, or not observed) and the time taken to identify funduscopic findings were assessed in pretest and posttest.

Secondary outcome measures

An anonymous, self-administered paper questionnaire was employed to assess study participants' confidence in performing funduscopic examinations and their motivation for performing funduscopic examinations before and after their respective training sessions. Each question was answered on a five-point Likert scale (from 1 - Strongly disagree to 5 - Strongly agree). The questionnaire was developed by KS, SS, and KN based on prior published research and focus group discussions.[32]

Statistical analysis

We performed descriptive and bivariate analyses to describe our sample. The diagnostic accuracy in funduscopic findings, time taken to identify funduscopic findings, as well as the confidence and motivation for performing funduscopic examinations between the two groups were compared by using the two-way analysis of variance (ANOVA). All statistical analyses were performed using IBM SPSS version 26.0 (IBM Corp. Armonk, NY).

Focus group

A qualitative inquiry was conducted following the quantitative study to help explain the quantitative results. A sample of 36 medical students was randomly selected from the quantitative study participants (18 from the flipped classroom group and 18 from the traditional classroom group).[33] After obtaining informed consent, we conducted six focus groups lasting about 30 minutes, each considering workflow impacts and participants' fatigue. Groups were organized separately with the students who participated in the flipped classroom approach (3 groups, n = 18) and those who participated in the traditional classroom (3 groups, n = 18).

Trained moderators (KS and DY) asked open-ended questions about students' perception of the effectiveness of flipped classroom and traditional teaching of fundus examination (diagnostic accuracy and the time taken to identify funduscopic findings). They asked about what went well and what did not go well in the educational session, and the significance of the flipped classroom approach (Supplement 2). The focus groups were recorded and transcribed verbatim. The transcripts were analyzed using deductive content analysis drawing upon the revised Bloom's taxonomy as the coding frame, with the cognitive process dimensions as the theme categories and subcategories.[34,35] Open coding of the focus groups transcripts was done by KS and DY. The authors independently read and coded all transcripts, and then discussed, identified, and agreed on the coding of the descriptors. Inter-rater degree of agreement between two researchers was assessed using the Cohen's kappa statistics.

KY derived theme categories and subcategories as they emerged from the data. To ensure credibility of the findings, the theme categories and subcategories were regularly discussed with and reviewed for content by DY, who has extensive experience in qualitative research.[18] Concepts for each of the cognitive process dimension in the revised Bloom's taxonomy [16] were analyzed, and the number of units of analysis for each concept was counted (Supplement 3). We have grouped similar codes into a theme and then checked to see which dimension of the cognitive process it corresponded.

Results

All 104 students completed the quantitative arm of this study. The mean age of the participants was 23.4 years (± 1.8), and 75.0% were men. We found no statistically significant differences in demographics between the flipped classroom and traditional classroom groups.

The mean diagnostic accuracy scores in the posttest significantly increased from pre-test in both intervention and control groups (Table 1). The mean diagnostic accuracy score increased from 36.6% (56/153 examinations) to 63.4% (97/153 examinations) in the intervention group, and from 28.3% (45/159 examinations) to 34.6% (55/159 examinations) in the control group. The effect size of the flipped classroom instructional method on the diagnostic accuracy was 0.43, with the instructional method explaining 95% of variance in the diagnostic accuracy (F (1, 310) = 11.0, $p = 0.001$, ώ = 0.43).

The mean time taken to identify funduscopic findings in each post-test significantly decreased from pre-test in both intervention and control groups (Table 1). The mean time in pre-test and post-test were 85.4 ± 11.7sec to 66.9 ± 20.8sec in the intervention group, and 85.3 ± 10.5sec to 76.3 ± 20.8sec in the control group. A two-way ANOVA revealed a significant effect for educational methods. In the intervention group, the time was significantly shorter (F (1, 310) = 14.7, $p < 0.001$, ώ = 0.50).

Confidence of funduscopic examinations and motivation to learn funduscopic examinations significantly increased from pre-test to post-test in both the flipped-classroom group and the traditional classroom group (Table 2). The confidence score increase in the post-test vs. pre-test was 2.3 ± 1.3 to 3.8 ± 0.9 in the flipped classroom group and 2.0 ± 0.8 to 2.8 ± 1.0 in the traditional classroom group. A two-way ANOVA revealed a significant effect for the educational method. In the flipped classroom group, the confidence of funduscopic examinations was significantly higher than for the traditional classroom group: F (1,102) = 9.6, $p = 0.002$, ώ = 0.31).

The motivation score increase in the post-test vs. pre-test was 3.5 ± 0.7 to 4.4 ± 0.6 in the flipped classroom group and 3.3 ± 1.0 to 3.9 ± 0.9 in the traditional classroom group. A two-way ANOVA revealed a significant effect for the educational method. In the flipped classroom group, the motivation was significantly higher F (1,102) = 24.1, $p < 0.001$, ώ = 0.34) than in the traditional classroom group.

Content analysis

The effect of educational method (flipped classroom vs traditional lecture-based teaching) on the students' cognitive processes intervention and control group was explored. The categories for our analysis were preset according to the six cognitive process levels from the revised Bloom's taxonomy. Following open coding, similar codes were grouped into a theme and then each theme checked against the revised Bloom's taxonomy's definitions to see to which level of the cognitive process it corresponded. Thematic saturation was reached after analyzing transcripts from 6 focus groups (3 with the flipped classroom students – the intervention group – and 3 with the traditional teaching students – the control group) The absolute frequencies of the codes for each cognitive process dimension for our data are presented in Tables 3 and 4. In the intervention group, a total of 12 categories and 20 subcategories were identified corresponding to the five levels of the revised Bloom's taxonomy[15]: remember, understand, apply, analyze, evaluate (Table 3). A total of 5 categories and 6 subcategories were identified in the control group corresponding only to three levels of the revised Bloom's taxonomy: understand, apply, analyze (Table 4). The interrater reliability was substantial (Cohen's kappa = 0.81).

Discussion

This study suggests that the flipped classroom teaching method is superior to the traditional teaching method for fundus examination training among medical students. Our results showed that the students in the flipped classroom group significantly improved their diagnostic accuracy of fundus examination and significantly reduced their observation time for fundus examination compared to the traditional teaching group. This was because the flipped classroom teaching method enabled higher levels of cognitive activity according to the revised Bloom's taxonomy.[15–17]

The flipped classroom teaching method may offer advantages for medical education by preparation for basic knowledge of fundus examination. Using the flipped classroom approach, the knowledge required for fundus examination can be acquired at the preparation stage such as medical students.[12] This knowledge provides the basis for fundus observation and interpretation of findings. It is considered that the skill of fundus examination was improved by performing high-dimensional performances such as application and analysis by having the knowledge corresponding to this foundation.

This study also showed that the students in the flipped classroom group significantly increased their confidence in and motivation for performing fundus examinations, compared to the traditional teaching group. Low confidence levels on the part medical interns and attending physicians in their fundoscopic examination skills were linked to decreased rates of providing this exam.[9–11] One challenge for teaching the fundus examination is that medical students and physicians alike have reduced confidence in using an ophthalmoscope.[36, 37] As such, few clinicians perform ophthalmoscopy, and many who do are unable to reliably detect abnormalities of the ocular fundus. Our study indicates that the use of the flipped classroom approach improves the confidence of medical students in fundus examination; thus, it is expected that the frequency of funduscopic examination in the clinical settings will increase. This was attributed to the fact that students repeatedly viewed the preparatory video material in the flipped classroom, which increased their understanding of fundus examination.

Furthermore, the flipped classroom teaching method increased ”students' motivation to learn fundus examinations. In light of psychological findings, it has been consistently demonstrated that learning motivation predicts learning outcomes, and there is no dispute about the importance of learning motivation as a foundation for knowledge and skill acquisition, thinking, and expression.[38] Thus, the flipped classroom teaching method in fundus examination has the potential to motivate the medical students to continue to perform fundus examinations.

Limitations

The present research was conducted with a simulator, not with real patients. Although our intervention was effective in the simulation settings, it is necessary to verify whether it can be used, with the same effects, with real patients. Additionally, there is a possibility that the educational effect of the flipped classroom teaching for fundus examination may depend on the teaching skills of faculty. However, in our study, we designed the instruction and trained the faculty to minimize the effects of faculty teaching skills. Furthermore, this study was conducted in classrooms where the faculty deliberately chose to experiment with the flipped classroom approach to teaching fundus examination; thus, our results may not be generalizable or transferrable beyond the specific population from which the sample was drawn. Additional validation is needed to determine the applicability of these results to residents and general physicians, too.

Conclusion

Teaching funduscopic examination to medical using the flipped classroom approach leads to improved diagnostic accuracy, confidence, and motivation for funduscopic examinations while reducing total examination time. The flipped classroom is an effective and efficient method for teaching the fundoscopic examination techniques, leading to improved competency outcomes in medical students.

Declarations

Ethics approval and consent to participate

This research was performed in accordance with the Declaration of Helsinki and approved by the Ethics Review Committee of the Chiba University Graduate School of Medicine (Chiba, Japan). The researchers explained to the participants and obtained their informed and voluntary consent. As the researchers took charge of the faculty members, the conflict of interest could arise between the researchers and the participants (the students). As a countermeasure, the faculty members explained to the students that the study would not be used for university grading.

Clinical trial registration

This study was registered with the University Hospital Medical Information Network Clinical Trials Registry on 08/02/2020 (Unique trial number: UMIN 000039434).

Consent for publication

Not applicable.

Availability of data and materials

The raw dataset supporting the conclusions of this article is available from the corresponding author upon request.

Competing interests

The authors have no conflicts of interest directly relevant to the content of this article.

Funding

Not applicable.

Authors’ contributions

KS, SS, YH, and KN contributed to the study conceptualization and design. KS, SS, and YH contributed to acquisition of the data. KS, CR, DY, SS, YH, KN, and MI analysis and interpretation of the data. KS wrote the main manuscript text and prepared all figure and tables. CR, DY, SS, YH, KN, and MI reviewed the manuscript.

Acknowledgments

The authors thanks MGH institute of Health Professions for Roger A. Edwards, ScD, Director of Health Professions Education, Associate Professor, Department of Health Professions Education, MGH Institute of Health Professions, Boston, MA.

References

1. Day LM, Wang SX, Huang CJ. Nonmydriatic fundoscopic imaging using the pan optic iExaminer system in the pediatric emergency department. *Acad Emerg Med*. 2017;24(5):587-594.
2. Mottow-Lippa L. Ophthalmology in the medical school curriculum: reestablishing our value and effecting change. *Ophthalmology*. 2009;116(7):1235-1236.
3. Medical Education Model Core Curriculum. Ministry of Education, Culture, Sports, Science and Technology. http://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2017/06/28/1383961_01.pdf. Published 2016. Accessed January 9, 2021.
4. Shikino K, Suzuki S, Hirota Y, Kikukawa M, Ikusaka M. Effect of the iExaminer Teaching Method on Fundus Examination Skills: A Randomized Clinical Trial. *JAMA Netw Open*. 2019;2(9):e1911891.
5. Mottow-Lippa L, Boker JR, Stephens F. A prospective study of the longitudinal effects of an embedded specialty curriculum on physical examination skills using an ophthalmology model. *Acad Med*. 2009;84(11):1622-1630.
6. Wu EH, Fagan MJ, Reinert SE, Diaz JA. Self-confidence in and perceived utility of the physical examination: a comparison of medical students, residents, and faculty internists. *J Gen Intern Med*. 2007;22(12):1725-1730.
7. Kikukawa M, Ogawa H. Frequency of use and awareness survey of fundoscopy by the resident of Fukuoka MIN-IREN and the attending physician of internal medicine. [In Japanese] *Medical Education*. 2007;38:S70.
8. Dalay S, Umar F, Saeed S. Fundoscopy: a reflection upon medical training? *Clin Teach*. 2013; 10(2): 103-106.
9. Roberts E, Morgan R, King D, Clerkin L. Funduscopy: a forgotten art? *Postgrad Med J*. 1999;75(883):282-284.
10. Gupta RR, Lam W-C. Medical students' self-confidence in performing direct ophthalmoscopy in clinical training. *Can J Ophthalmol*. 2006;41(2):169-174.
11. Lippa LM, Boker J, Duke A, Amin A. A novel 3-year longitudinal pilot study of medical students' acquisition and retention of screening eye examination skills. *Ophthalmology*. 2006;113(1):133-139.
12. Moffett J. Twelve tips for "flipping" the classroom. *Med Teach*. 2015;37(4):331-336.
13. Prober CG, Heath C. 2012. Lecture halls without lectures--a proposal for medical education. *N Engl J Med*. 366(18):1657-1659.
14. Jonathan B, Aaron S. 2012. *Flip Your Classroom: Reach Every Student in Every Class Every Day*. Alexandria, VA: International Society for Technology in Education; 2012.
15. Anderson LW, Krathwohl DR, Airasian P, et al. *A taxonomy for learning, teaching and assessing: a revision of Bloom's taxonomy*. New York, NY: Longman; 2001.
16. Bloom BS, Englehart MD, Furst EJ, Hill WH, Krathwohl DR. *Taxonomy of educational objectives, the classification of educational goals, Handbook I: Cognitive domain. 1st Ed*. New York, NY: Longmans, Green, and Co.; 1956.
17. Morton DA, Colbert-Getz JM. Measuring the impact of the flipped anatomy classroom: The importance of categorizing an assessment by Bloom's taxonomy. *Anat Sci Educ*. 2017;10(2):170-175.
18. Lucchetti, ALG, da Silva Ezequiel, O, de Oliveira. IN, Moreira-Almeida, A., Lucchetti, G., 2018. Using traditional or flipped classrooms to teach "Geriatrics and Gerontology"? Investigating the impact of active learning on medical students' competences. *Med Teach.* 40(12):1248-1256.
19. Jamaludin R, Osman SZ. 2014. The Use of a Flipped Classroom to Enhance Engagement and Promote Active Learning. *J of Educ and Pract*. 5(2);124-131.

20. Almasseri, M, AlHojailan, MI. How flipped learning based on the cognitive theory of multimedia learning affects students' academic achievements. *Journal of Computer Assisted Learning*. 2019:35(6): 769-781.
21. Stockwell BR, Stockwell MS, Cennamo M, Jiang E. Blended Learning Improves Science Education. *Cell*. 2015;162(5):933-936.
22. Crouch CH, Mazur E. Peer instruction: Ten years of experience and results. *Am J Phys*. 2001; 69: 970–977.
23. Hew KF, Lo CK. Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Med Educ*. 2018;18(1):38.
24. Nelson BP, Hojsak J, Dei Rossi E, Karani R, Narula J. Seeing Is Believing: Evaluating a Point-of-Care Ultrasound Curriculum for 1st-Year Medical Students. *Teach Learn Med*. 2017;29(1):85-92.
25. Barbour RS. The case for combining qualitative and quantitative approaches in health services research. *J Health Serv Res Policy*. 1999;4(1):39-43.
26. Malterud K. The art and science of clinical knowledge: Evidence beyond measures and numbers. *Lancet*. 2001;358(9279):397-400.
27. Côté L, Turgeon J. Appraising qualitative research articles in medicine and medical education. *Med Teach*. 2005 ;27(1):71-5.
28. Creswell JW, Klassen AC, Plano Clark VL, Smith KC for the Office of Behavioral and Social Sciences Research. *Best practices for mixed methods research in the health sciences.Qualitative Social Work*. 12(4):541-545.
29. Creswell JW, Plano Clarck VL. *Designing and Conducting Mixed Method Research*. *Third edition.* Sage Publications, Inc.; 2017.
30. Goedhart NS, Blignaut-van Westrhenen N, Moser C, Zweekhors MBM. The flipped classroom: supporting a diverse group of students in their learning. *Learning Environments Research*. 2019; 22:297–310.
31. iEXAMINER.https://www.welchallyn.com/en/microsites/iexaminer.html.Published 2018. Accessed January 9, 2021.
32. Sommer NN, Treitl KM, Coppenrath E, et al. Three-Dimensional High-Resolution Black-Blood Magnetic Resonance Imaging for Detection of Arteritic Anterior Ischemic Optic Neuropathy in Patients With Giant Cell Arteritis. *Invest Radio* 2018;53(11):698-704.
33. Patton, MQ. *Qualitative Evaluation and Research Methods.* Thousand Oaks, CA: Sage. 2015.
34. Elo S, Kyngäs H. The qualitative content analysis process. *J Adv Nurs*. 2008;62(1):107-115.
35. Graneheim UH, Lindgren BM, Lundman B. Methodological challenges in qualitative content analysis: A discussion paper. *Nurse Educ Today*. 2017;56:29-34.
36. Kelly LP, Garza PS, Bruce BB, Graubart EB, Newman NJ, Biousse V. Teaching ophthalmoscopy to medical students (the TOTeMS study). *Am J Ophthalmol*. 2013;156(5):1056-1061.e10.
37. Yokokawa D, Shikino K, Ikegami A, et al. 2020. Do Checklist-Induced Behavioral Changes Improve Self-Confidence in Fundoscopic Examination? A Mixed-Methods Study. *Int J Gen Med*. 23(13):1219-1228.
38. Mayer RE and Alexander PA (Eds.), *Handbook of research on learning and instruction*. New York and London: Routledge; 2011.

Tables

Table 1. Diagnostic accuracy and time taken to identify funduscopic findings

	Intervention group (n = 51)		Control group (n = 53)		Two-way ANOVA	
	Pre test Mean	Post test Mean	Pre test Mean	Post test Mean	F(1, 310)	*p*-value
Diagnostic accuracy, % (n)	36.6 (56/153)	63.4 (97/153)	28.3 (45/159)	34.6 (55/159)	11.0	0.001
Time taken to identify funduscopic findings, sec (SD)	85.4 (11.7)	66.9 (20.8)	85.3 (10.5)	76.3(20.8)	14.7	<0.001

Table 2. Confidence of funduscopic examinations, and motivation to learn funduscopic examinations

	Intervention group (n = 51)		Control group (n = 53)		Two-way ANOVA	
	Pre teaching Mean	Post teaching Mean	Pre teaching Mean	Post teaching Mean	F(1, 102)	*p*-value
Confidence of funduscopic examinations* (SD)	2.3 (1.3)	3.8 (0.9)	2.0 (0.8)	2.8 (1.0)	9.6	0.002
Motivation to learn funduscopic examinations* (SD)	3.5 (0.7)	4.4 (0.6)	3.3 (1.0)	3.9 (0.9)	24.1	<0.001

*1: Strongly disagree, 5: Strongly agree

Table 3. Absolute Frequencies of Codes for Each Theme (Intervention Group)

Theme (Cognitive process dimension)	Category	Subcategory	Number of codes
Evaluate	Metacognition of learning	Improve learning motivation	2
		Discovering new challenges	1
Analyze	Effective learning	Efficient acquisition of fundus examination skill	6
		Effectiveness of preparation	4
		Establishing by repetition	1
		Linking knowledge and practice	1
	Analysing procedure	Analysis of fundus examination performance	3
	Psychological safety	Feeling safe for practicing	2
		Anxiety about preparation	3
Apply	Learning motivation	Motivation for performing real patient	3
		Motivation from successful experiences	1
	Using abstractions	Application of knowledge obtained in preparation	1
		Practice that understands the points fundus examination	1
	Concrete experience	Imaging of diagnostic procedures	1
	Problem solving	Trouble shooting of equipment	1
Understand	Understanding procedure	Observation method of fundus	9
		Usage instructions of fundoscope	1
	Efficient understanding	Efficient understanding of fundus examination	2
Remember	Memory retention	Improve memory retention through preparation	6
	Acquisition of knowledge	Acquisition of necessary knowledge for fundus examination	4

Table 4. Absolute Frequencies of Codes for Each Theme (Control Group)

Theme (Cognitive process dimension)	Category	Subcategory	Number of codes
Analyze	Analysing procedure	Analysis of fundus examination performance	1
Apply	Concrete experience	Practice of fundus observation	7
	Learning motivation	Motivation from successful experiences	1
	Using abstractions	Application of knowledge obtained in lecture	1
Understand	Understanding procedure	Observation method of fundus	2
		Usage instructions of fundoscope	2

Figures

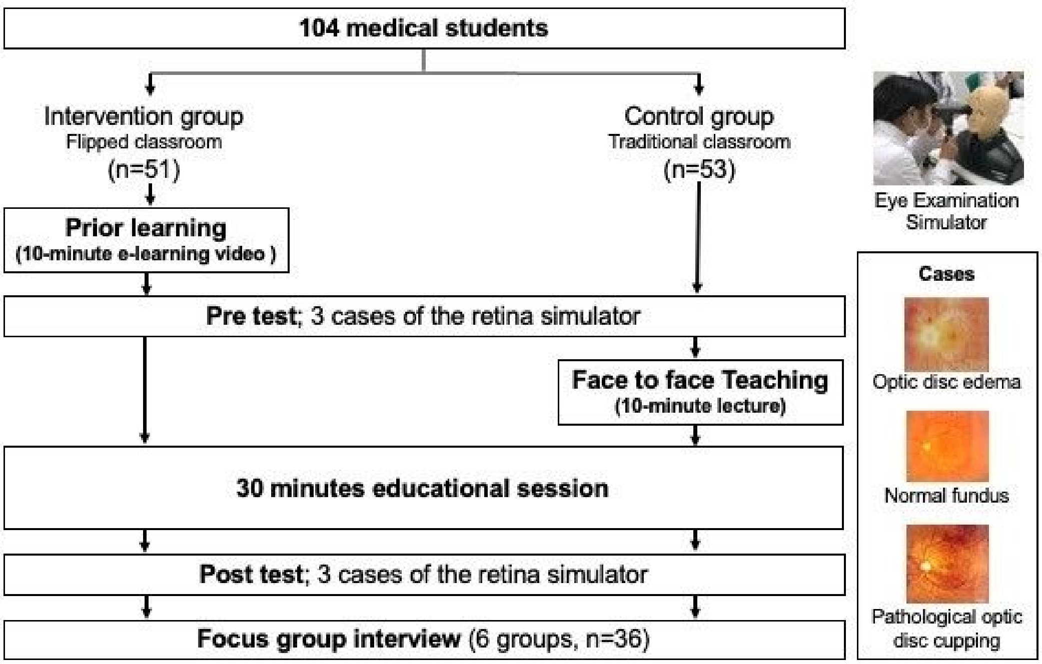

Figure 1

Reaserch flow

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementary1Shikino.docx
- Supplementary2Shikino.docx
- Supplementary3Shikino.docx