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Knowledge and skills acquisition in medical students

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SUMMARY

This thesis comprises several chapters on the relation between aspects of the curriculum and students' knowledge development and skill acquisition at different levels, ranging from the effect of feedback characteristics to the effect of massed or spaced curricula. The main research question of this thesis is: How do aspects of the curriculum relate to students' knowledge development and skill acquisition? To answer our research questions and because of the complexity of studying aspects of the curriculum, we used different methodologies.

In **Chapter 2** and **3** the relation between curriculum characteristics and knowledge development was explored. In order to do so we chose oncologic knowledge since many medical disciplines are represented in this topic.

In **Chapter 2**, students' knowledge development was explored by analyzing data from the Dutch progress test on 1440 medical students of four undergraduate medical schools. To better understand the differences between the curricula, the four oncology curriculum coordinators were interviewed. Students' knowledge development was compared using mixed model analysis. The results demonstrated that two curriculum characteristics seem to have a positive impact on students' knowledge development: the presence of a pre-internship course and concentration of the discipline in one semester. Although it seems that these two characteristics benefit students' knowledge development, this study was exploratory and, therefore, implications based on the results do not presuppose causality.

In **Chapter 3**, the findings of Chapter 2 were investigated in more depth and in a more controlled environment, although the study was still conducted in a naturalistic setting. For this purpose, the development of students' knowledge of oncology in one medical school was compared between students who were taught in a concentrated semester and students who were taught in a spaced format. The medical school offers a six-year medical training; the first three years are predominantly preclinical and the last years predominately clinical. Comparing these two parallel cohorts decreased the number of confounders, since the context (within the same university), teachers, teaching methods and assessment were similar in both cohorts. The results showed that at the beginning of preclinical training, students in the spaced curriculum scored higher and at the end of preclinical training, students in the spaced curriculum scored lower than students in the concentrated semester. The results of Chapter 2 and 3 suggest that students' knowledge development may be related to the way the content is presented over time: distributed over a longer period or concentrated in one semester.

In **Chapter 4** and **5** the relation between assessment characteristics and knowledge development was investigated.

Medical students do not only acquire knowledge, but they are also expected to apply knowledge and reflect on it. In **Chapter 4**, the development of students' ability to apply their knowledge and their judgment of knowledge were investigated. Since we were interested in students' scores on lower and higher order questions during their preclinical and clinical training, progress test data from the beginning and end of their preclinical or clinical training were analyzed. To investigate students' cognitive processing

development, specific assessment characteristics were used, based on Bloom's taxonomy: lower-order questions requiring students to only recall their knowledge and higher-order requiring students to apply their knowledge. To investigate the educational aspect of the judgment of knowledge, the question mark option in successive progress tests was used. Subsequently, the growth in students' ability to apply and judge their knowledge was compared in the preclinical and clinical phase. Whereas preclinical (Year 1 and 3) and Year 4 students scored lower on vignette questions (higher order), the Year 6 students scored higher on vignette questions than on simple questions (lower order). Students' judgement of knowledge decreased over time for both cohorts, possibly indicating that the question mark option does not support students' judgment of knowledge development.

In addition to investigating the educational aspect of judgement of knowledge (Chapter 4), it is important to verify the effect of adding the "question mark option" as an assessment characteristic on students' scores. In **Chapter 5**, the psychometric properties of two scoring methods, a number-right scoring and the formula scoring (with "question mark option"), were compared. More specifically, we investigated whether the question mark option as an assessment characteristic provides less dysfunctional items and a more reliable score in a 2x2 crossover design. The majority of dysfunctional items was found in the formula scoring test condition. Furthermore, the reliability for the tests using number-right scoring were higher than for formula scoring. Chapter 4 and 5 suggest that adding the question mark option as an assessment characteristic may not be optimal for two reasons. First, as students progress, more questions were guessed and answered incorrectly. Second, the addition of the question mark decreases the reliability of the test and increase the number of dysfunctional items.

In **Chapter 6 and 7** the relation between curriculum characteristics and skill acquisition was investigated.

During medical training, medical students do not only acquire knowledge, but also skills. Students should have the opportunity to practice and receive feedback during their skill acquisition and retention. Without practice and feedback, learning a new technical skill would be very challenging. Trainees may practice either in one session, known as massed training, or in multiple sessions spread over time, known as spaced training. In **Chapter 6** a systematic review was conducted to investigate the effect of spacing training sessions on long-term retention of surgical skills. The Medline, PsycINFO, Embase, Eric and Web of Science online databases were searched. Only randomized trials with a sample of medical trainees acquiring surgical motor skills in which the spacing effect was reported were included in the study. The quality and bias of the articles were assessed using the Cochrane Collaboration's risk of bias assessment tool. 11 articles met all inclusion criteria and were included. The overall quality of the articles was "moderate". Students in the spaced condition scored higher on a retention test than students in the massed condition. Although the optimal gap between study sessions

remains unclear, our systematic review suggests that when designing a technical skill training, spacing the training sessions improves students' skill retention when compared to massed practice.

In **Chapter 7** a randomized experiment was conducted to investigate the effect of expert and augmented feedback on the acquisition and retention of a complex medical skill. 36 medical students were randomly assigned to one of three types of feedback: expert feedback only (EF), augmented visual feedback (simulator help screen) (HS), and expert feedback with augmented visual feedback (EF+HS). Immediately after the training, students in the EF group were faster than students in the two other groups. After 11 days, students in the EF+HS group scored significantly higher for image quality than students in the two other groups.

This thesis has demonstrated that there is a relation between a few aspects of the curriculum and knowledge development and skill acquisition. Furthermore, this thesis has shown how and when the spacing effect may benefit students' knowledge development and skill acquisition, how the "I don't know" option affects students' scores and, finally, that different sources of feedback are needed to enhance students' skill acquisition and retention.

SAMENVATTING

De hoofdstukken in dit proefschrift behandelen onderzoeken naar de relatie van curriculumkenmerken met kennisontwikkeling en het verwerven van vaardigheden, variërend van effecten van verschillende bronnen van feedback tot effecten van curricula waarin vaardigheden worden geoefend in één aaneengesloten sessie of in meerdere sessies, verspreid over langere tijd. De hoofdvraag van dit proefschrift is: Hoe verhouden curriculumkenmerken zich tot kennisontwikkeling en het verwerven van vaardigheden van studenten? Om deze onderzoeksvraag te kunnen beantwoorden en vanwege de complexiteit van de te onderzoeken aspecten van het curriculum, werd gebruik gemaakt van diverse onderzoeksmethoden.

In de **Hoofdstukken 2 en 3** wordt onderzoek beschreven naar de relatie tussen curriculumkenmerken en kennisontwikkeling van geneeskunde studenten. We hebben voor kennis van oncologie gekozen omdat hierin veel disciplines vertegenwoordigd zijn.

Hoofdstuk 2 rapporteert explorerend onderzoek naar de kennisontwikkeling van 1440 geneeskunde studenten van vier Nederlandse universiteiten aan de hand van hun resultaten op de landelijke voortgangstoets. Om inzicht te krijgen in de verschillen tussen de curricula werden de vier oncologie coördinatoren geïnterviewd. De kennisontwikkeling van de studenten werd onderzocht aan de hand van een “mixed model analysis”. De resultaten laten zien dat twee curriculumkenmerken een positieve invloed lijken te hebben op de kennisontwikkeling van studenten: de mogelijkheid een voorbereidende cursus op een coschap te volgen en concentratie van het onderwijs rondom een discipline in 1 semester. Gezien het exploratieve karakter van het onderzoek dient voorzichtigheid betracht te worden bij de interpretatie van de resultaten.

In **Hoofdstuk 3** wordt dieper ingegaan op de resultaten van de studie uit Hoofdstuk 2. Het onderzoek werd uitgevoerd onder gecontroleerde, maar nog steeds realistische omstandigheden. De kennisontwikkeling van studenten op het gebied van oncologie werd onderzocht binnen één geneeskunde opleiding, een 6-jarige opleiding waarvan de eerste 3 jaren hoofdzakelijk preklinisch en de laatste 3 jaren hoofdzakelijk klinisch van aard waren. Hierbij werd de kennisontwikkeling van studenten die het oncologie onderwijs geconcentreerd binnen één semester volgden vergeleken met de kennisontwikkeling van studenten die hetzelfde onderwijs volgden, maar dan gefaseerd over een langere periode. Een vergelijking tussen deze twee parallele cohorten zorgde ervoor dat het aantal mogelijk beïnvloedende factoren verminderd werd aangezien de context (dezelfde universiteit), de docenten en de onderwijs- en toetsmethoden vergelijkbaar waren. Uit de resultaten bleek dat studenten in het gefaseerde curriculum aan het begin van de preklinische fase hogere en aan het eind van de preklinische fase lagere scores hadden dan studenten in het curriculum waar het onderwijs in zijn geheel binnen een semester werd aangeboden.

De resultaten van de onderzoeken uit Hoofdstuk 2 en 3 suggereren dat kennisprogressie van studenten gerelateerd kan zijn aan de wijze waarop de inhoud wordt aangeboden: gefaseerd over een langere periode of geconcentreerd binnen één semester.

In de **Hoofdstukken 4 en 5** worden studies beschreven waarin gekeken werd naar de relatie tussen toetskenmerken en kennisonwikkeling.

Van medische studenten wordt niet alleen verwacht dat zij kennis vergaren, maar ook dat zij die kennis kunnen toepassen en daarop reflecteren. In **Hoofdstuk 4** werden ontwikkeling in het vermogen om kennis toe te passen en het eigen oordeel van studenten over hun kennis onderzocht.

Om ontwikkelingen in cognitieve informatieverwerking te bestuderen, werden specifieke toetskenmerken toegepast die gebaseerd waren op Bloom's taxonomy: bij het beantwoorden van lagere orde toetsvragen werd van studenten verlangd dat zij de kennis konden reproduceren en bij hogere orde toetsvragen werd van hen verlangd dat zij de kennis konden toepassen. Aangezien we geïnteresseerd waren in scores van studenten op lagere en hogere orde toetsvragen tijdens de preklinische en klinische fase van de opleiding, werden voortgangstoetsdata van de studenten aan het begin en einde van de preklinische fase of aan het begin en einde van de klinische fase onderzocht.

Om meer inzicht te krijgen in het educatieve aspect van het oordeel van studenten over hun eigen kennis, werd hun gebruik van de vraagtekenoptie in opeenvolgende voortgangstoetsen bestudeerd. Vervolgens werd groei in vermogen van studenten om kennis toe te passen en eigen kennis te beoordelen onderzocht en vergeleken. Terwijl eerste- en derdejaars studenten in de preklinische fase en vierdejaars studenten in het eerste jaar van de masterfase *lager* scoorden op vignetvragen (hogere orde vragen) dan op simpele vragen (lagere orde vragen), scoorden zesdejaars studenten in het laatste jaar van de masterfase *hoger* op vignetvragen dan op simpele vragen. Het oordeel van studenten over hun eigen kennis nam in de loop van de tijd af voor beide cohorten, hetgeen mogelijk aangeeft dat het gebruik van een vraagtekenoptie ontwikkeling van het oordeel over eigen kennis niet stimuleert.

Naast het onderzoeken van het educatieve aspect van het beoordelen van de eigen kennis (Hoofdstuk 4) is het belangrijk om na te gaan wat het effect is van het gebruik van de vraagtekenoptie als toetskenmerk op scores van studenten. In **Hoofdstuk 5** worden de psychometrische eigenschappen van twee scoremethoden voor multiple choice vragen vergeleken, "number-right scoring" waarbij het aantal goed beantwoorde vragen wordt opgeteld en "formula scoring" waarbij de vraagtekenoptie en het aantal antwoordmogelijkheden per vraag worden verrekend. Meer specifiek, we onderzochten in een 2x2 crossover-design of de vraagtekenoptie als toetskenmerk minder disfunctionele items (vragen) en een betrouwbaarder score oplevert. Hoofdstuk 4 en 5 suggereren dat toevoeging van de vraagtekenoptie mogelijk niet optimaal is. Ten eerste omdat studenten meer vragen gokten en fout beantwoordden en ten tweede omdat de betrouwbaarheid van de toets verminderde en het aantal disfunctionele vragen toenam.

In de studies beschreven in de **Hoofdstukken 6 en 7** werd onderzoek uitgevoerd naar de relatie tussen curriculumkenmerken en het verwerven van vaardigheden.

Tijdens de medisch opleiding verwerven studenten niet alleen kennis, maar ook vaardigheden. Studenten zouden tijdens hun opleiding in de gelegenheid gesteld

moeten worden om te oefenen en feedback te krijgen op het aanleren en onderhouden van vaardigheden. Zonder oefening en feedback zou het aanleren van een nieuwe vaardigheid een hele uitdaging zijn. Studenten kunnen oefenen in één aaneengesloten sessie (massed training) of gefaseerd over meer sessies die verdeeld zijn over langere tijd (spaced training).

In **Hoofdstuk 6** wordt een systematisch literatuuronderzoek beschreven naar het effect van een gefaseerde training op lange-termijn retentie van chirurgische vaardigheden. Hiervoor werden de Medline, PsycINFO, Embase, Eric en Web of Science databases doorzocht. Alleen gerandomiseerde studies die waren uitgevoerd met medische studenten die chirurgische motorische vaardigheid aanleerden en waarin een "spacing effect" was vermeld, werden in de analyse opgenomen. Voor de beoordeling van de kwaliteit van de artikelen werd de "Cochrane Collaboration's risk of bias assessment tool" gebruikt. 11 artikelen voldeden aan de inclusiecriteria. De methodologische kwaliteit van de artikelen was "middelmatig". Medische studenten in de gefaseerde conditie scoorden hoger op een retentietoets dan studenten in de conditie met een aaneengesloten training. Hoewel de optimale tijdsinterval tussen de sessies nog steeds onduidelijk is, suggereert het literatuuronderzoek dat met het oog op het ontwikkelen van een training in technische vaardigheden een training die gefaseerd wordt aangeboden de retentie verbetert ten opzichte van één aaneengesloten trainingssessie.

In **Hoofdstuk 7** werd een gerandomiseerd experiment uitgevoerd om het effect te onderzoeken van feedback van een expert en "augmented feedback" op het aanleren en retentie van een complexe medische vaardigheid. 36 medische studenten werden at random toegewezen aan één van drie condities waarin de aard van de feedback verschilde: alleen feedback van een expert (EF), augmented optische feedback (door middel van een simulator + helpscreen) (HS) en een combinatie van de twee (EF+HS). Direct na de training bleek dat studenten die feedback van een expert hadden ontvangen sneller waren dan studenten van de andere twee groepen. Na 11 dagen scoorden studenten van de EF+HS groepen significant hoger op kwaliteit van de door hen gemaakte afbeelding dan studenten van de beide andere groepen.

Dit proefschrift heeft aangetoond dat er een relatie is tussen enkele curriculumaspecten en kennisontwikkeling en het verwerven van vaardigheden. Uit dit proefschrift kwam ook naar voren hoe en wanneer spreiding van de stof voordeel op kan leveren voor de ontwikkeling van kennis en vaardigheden van studenten, hoe de vraagtekenoptie toetsscores van studenten beïnvloedt en dat er verschillende bronnen van feedback nodig zijn om de ontwikkeling en retentie van vaardigheden te bevorderen.

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