

Putting the Testing-effect to the Test
Why and When is Testing Effective for
Learning in Secondary School?

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Why and When is Testing Effective for Learning in Secondary School?

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CHAPTER 1

General Introduction

In this first chapter, an introduction to the testing-effect will be given, from both a theoretical and empirical point of view. In addition, a set of guidelines is presented based upon which the studies in this thesis were designed. At the end of the chapter the main research questions are introduced and an overview of the remaining chapters of this thesis are presented.

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Summary

Educators generally use tests as assessment or evaluation tools. Memory researchers, however, have found that tests can also be used as powerful learning tools; that is, tests can effectively support learning by enhancing long-term retention of successfully retrieved information (for an overview see Rawson & Dunlosky, 2011; Roediger & Butler, 2011; Roediger, Putnam, & Smith, 2011). This finding is commonly known as the testing-effect (or more recently as the retrieval practice effect) and holds that successfully retrieving information through testing is more effective for long-term retention than restudying the information an equal amount of time.

Most testing-effect research has been carried out in laboratory settings with simple learning tasks such as wordlists or word-pair lists. Only a few recent studies have attempted to investigate the testing-effect under more educationally relevant conditions. Of these studies most have focused on the testing-effect by university students, though such a strategy might also be an effective one for younger students. The aim of this dissertation is to investigate whether retrieval practice is an effective learning strategy for students in secondary education. As such it contributes to the relatively sparse body of research on these two issues.

In *Chapter 1* of the dissertation, a general introduction into the *New Theory of Disuse* (Bjork & Bjork, 1992) is given as a framework for understanding the cognitive principles underlying the testing-effect. Then, some guidelines for investigating and implementing the testing-effect in educational practice are presented. These guidelines are drawn from the theoretical underpinnings of the testing-effect and a large amount of research and are:

1. *Use short-answer (SA) questions*
2. *Let the students restudy (everything)*
3. *Repeatedly test the students*
4. *Test the same knowledge on the posttest*

The chapter continues with an overview of this dissertation and its main research questions which are: 1) How does prior testing – as compared to no prior

testing – affect attention allocation during subsequent study and does initial test performance play a role in such study behavior? 2) Does repeated testing – with restudy – facilitate application of principles and procedures on a delayed posttest, and, if so, do these effects transfer to isomorphic problems? and 3) Are secondary school students aware of the beneficial effects of retrieval practice, and, do they use it when they study in the normal school situation?

Chapter 2 presents an experiment that focuses on the first research question and investigates the attentional effects of testing. It studies whether answering test questions affect subsequent study behavior and if performance on those questions is of influence on that behavior. For that purpose, 56 German participants read (i.e., studied) a text and were then either tested and restudied the text, or restudied the text two more times. The results show a clear attention effect of testing in the sense that students in the study-test-condition looked longer – during restudy – at the information that was previously questioned as compared to participants in the study-only-condition, especially when they were not able to retrieve that information on the initial test; that is, they could not correctly answer the question. It is also found that these attentional effects benefit posttest performance in the sense that participants in the study-test-condition performed better on initially tested information and largely improved on initially incorrectly retrieved facts.

The second study, described in *Chapter 3*, explores whether a testing-effect also occurs for the application of principles and procedures. For that purpose, 38 high-school students either repeatedly studied a text on probability calculations, or studied the text, took a test on the content, restudied the text, and finally took the test a second time. Results show that testing not only leads to better retention of facts than restudying, but also to better application of the acquired knowledge (i.e., principles and procedures) in high-school statistics. In other words, testing seems not only to benefit fact retention, but also positively affects application. However, in the study reported in this chapter, the same questions are used on the initial test and the posttest. For educational practice, it is also important that students are able to use the knowledge acquired in one situation to new problems or to problems in new situations. To do this, the studies in *Chapter 4* examine whether answering application questions during an initial test also improves solving new, isomorphic problems. In the first experiment, students either studied a text on probability calculations three times or studied the text, took an application test and restudied the text. After 1 week they completed a posttest which included repeated and new

application questions involving the same questions as on the initial test (only for the study-only-condition) or isomorphic problems. No beneficial effects of testing are found, either on repeated questions or on new questions. However, a second experiment was carried out in which students either studied the text four times or studied the text, took an application test, restudied the text and took the test a second time. Again, after 1 week they were given a posttest with repeated and isomorphic problems. The results show that although a single test does not benefit application of principles and procedures (experiment 1), repeated testing does lead to enhanced performance on a posttest containing identical problems and a posttest containing isomorphic problems (experiment 2).

The final study presented in *Chapter 5*, investigates whether secondary school students are actually aware of the benefits that testing can have and if they use it during self-study. For that purpose, 321 students secondary education filled-out a survey on study behavior and the use of testing for learning. The results obtained are congruent with the findings for university students and show that secondary school students rarely use retrieval practice when studying on their own. They are not aware of the beneficial effects of retrieval practice as memory enhancing learning tools, but rather, use retrieval as a diagnostic tool.

Chapter 6 provides an overview of the main findings of the studies in the dissertation, acknowledges the main limitations of the studies, discusses the findings in terms of practical and theoretical implications, and gives directions for future research in this field. In addition, the guidelines presented in Chapter 1 are adapted based on the findings of the studies and a refined set of guidelines for implementing the testing-effect into classroom practice is presented. These include:

1. *Use short-answer questions*
2. *Let the students restudy (especially when initial retrieval is low)*
3. *Repeatedly test the students*
4. *Test the same knowledge on the posttest using isomorphic questions*
5. *Create awareness of the beneficial effects of retrieval practice*

Samenvatting

Docenten en leerkrachten gebruiken toetsen normaliter als toets- of evaluatie instrument. Geheugenonderzoekers hebben echter ontdekt dat het maken van tussentijdse toetsen ook sterke leereffecten kan hebben. Dit betekent dat tussentijds toetsen leidt tot het beter onthouden van informatie die door het maken van de toetsvragen uit het geheugen opgehaald is (zie voor een overzicht Rawson & Dunlosky, 2011; Roediger & Butler, 2011; Roediger, Putnam, & Smith, 2011). Deze bevinding is beter bekend als het 'testing-effect' (tegenwoordig ook wel ophaal-effect genoemd) en houdt in dat het succesvol ophalen van informatie uit het geheugen leidt tot het beter onthouden van die informatie dan wanneer men een zelfde hoeveelheid tijd zou besteden aan het herbestuderen van de informatie.

De meeste studies die het testing-effect onderzocht hebben, zijn uitgevoerd in een laboratorium setting met eenvoudige materialen zoals woordenlijsten en woordparen. Er zijn slechts enkele recente studies die gepoogd hebben het testing-effect te onderzoeken in een meer onderwijskundig relevante context. De meeste van deze studies zijn uitgevoerd bij universiteitsstudenten. Dat roept de vraag op of de strategie niet ook zeer effectief zou kunnen zijn voor jongere leerlingen. Het doel van dit proefschrift was dan ook te onderzoeken of het ophalen van informatie middels tussentijds toetsen een effectieve leerstrategie is voor middelbare scholieren. In die zin draagt dit proefschrift bij aan de relatief schaarse studies die onderzoek gedaan hebben naar het testing-effect bij middelbare scholieren.

In *Hoofdstuk 1* van dit proefschrift wordt een algemene introductie gegeven in de *New Theory of Disuse* (Bjork & Bjork, 1992). Deze theorie dient als theoretisch kader voor het begrijpen van de cognitieve processen die ten grondslag liggen aan het testing-effect. Vervolgens zullen enkele richtlijnen gepresenteerd worden voor het onderzoeken of implementeren van het testing-effect in de praktijk. Deze richtlijnen zijn gebaseerd op het theoretisch kader en de immense hoeveelheid onderzoekingen die gedaan zijn naar het testing-effect. De richtlijnen zijn:

1. *Gebruik kort-antwoord vragen*
2. *Geef studenten de mogelijkheid om de stof (alles) te herbestuderen*
3. *Toets de studenten herhaaldelijk*
4. *Toets dezelfde kennis op de afsluitende toets*

Het hoofdstuk gaat verder met een overzicht van dit proefschrift en de onderzoeksvragen, welke zijn: 1) Hoe beïnvloedt tussentijds toetsen – in vergelijking met niet tussentijds toetsen – de aandachtverdeling tijdens het herbestuderen en heeft de prestatie op de tussentijdse toetsvragen een effect op dit herbestudeergedrag?, 2) Leidt herhaaldelijk toetsen – met herbestuderen – tot het beter kunnen toepassen van principes en procedures op een uitgestelde eindtoets, en indien dit zo is, leidt het ook tot het beter oplossen van nieuwe, isomorfe problemen? en 3) Zijn middelbare scholieren zich bewust van de positieve effecten van het ophalen van informatie uit het geheugen, en gebruiken zij deze strategie in de klas?

Hoofdstuk 2 presenteert een experiment dat zich richt op de eerste onderzoeksvraag van dit proefschrift, namelijk of het maken van een tussentijdse toets effect heeft op de aandachtverdeling tijdens herstudie. In het experiment werd gekeken of het beantwoorden van tussentijdse toetsvragen het herleesgedrag beïnvloedt en of prestatie op de vragen hierop van invloed is. Hiervoor werden 56 middelbare scholieren uit Duitsland gevraagd om een tekst te bestuderen. Na het bestuderen van de tekst kregen zij ofwel een tussentijdse toets over de tekst en konden vervolgens de tekst herbestuderen, ofwel zij herlezen de tekst twee keer. De resultaten laten een duidelijk effect zien van tussentijds toetsen op de aandachtverdeling. Studenten die tussentijds getoetst werden – vergeleken met leerlingen die niet tussentijds getoetst werden - keken tijdens herstudie langer naar de informatie die in de toetsvragen bevroegd werd. Dit is met name het geval voor de vragen waarop de leerlingen niet het juiste antwoord konden geven tijdens de tussentijdse toets. Daarnaast laten de resultaten zien dat leerlingen die tussentijds getoetst zijn veel beter scoren op dezelfde vragen in de eindtoets en veel vooruitgang boeken op vragen die zij tussentijds niet konden beantwoorden.

In het tweede experiment, beschreven in *Hoofdstuk 3*, is onderzocht of het testing-effect ook optreedt voor het toepassen van principes en procedures. Hiervoor werden 38 Nederlandse middelbare scholieren gevraagd om ofwel een

tekst over kans rekenen herhaaldelijk te lezen ofwel de tekst te lezen, een tussentijdse toets te maken, de tekst nogmaals te lezen en nogmaals de tussentijdse toets te maken. De resultaten laten zien dat tussentijds toetsen niet alleen leidt tot het beter onthouden van feiten, maar ook tot het beter kunnen toepassen van principes en procedures voor het vak statistiek. Met andere woorden, tussentijds toetsen lijkt niet alleen te leiden tot positieve effecten voor het onthouden van informatie, maar ook voor het toepassen ervan. Echter, in de studie in *Hoofdstuk 3* werd gebruik gemaakt van dezelfde vragen op de tussentijdse toets en op de eindtoets. Voor toepassing van het testing-effect in de praktijk is het echter belangrijker dat leerlingen in staat zijn om de kennis toe te passen op nieuwe problemen of situaties. Om te onderzoeken of tussentijds toetsen ook hiervoor bruikbaar is, wordt in de twee experimenten in *Hoofdstuk 4* onderzocht of het tussentijds beantwoorden van toepassingsvragen ook leidt tot het beter kunnen oplossen van nieuwe, isomorfe problemen op een eindtoets. In het eerste experiment bestudeerden de leerlingen de tekst herhaaldelijk of ze bestudeerden de tekst, maakten een tussentijdse toepassingstoets en herbestudeerden vervolgens de tekst. Een week later maakten de leerlingen een eindtoets, die bestond uit dezelfde toepassingsvragen en isomorfe vragen. De resultaten laten geen positieve effecten zien van tussentijds toetsen vergeleken met niet tussentijds toetsen op de eindtoets. Echter, een tweede experiment, waarin de tussentijdse toets nogmaals afgenomen werd na het herbestuderen, laat wel positieve effecten van tussentijds toetsen op het toepassen van informatie zien, zowel voor herhaalde vragen als ook voor nieuwe vragen. De resultaten tonen dus aan dat tussentijds toetsen ook leidt tot het beter kunnen toepassen van principes en procedures in nieuwe situaties, maar alleen wanneer leerlingen de tussentijdse toetsvragen meerdere keren beantwoord hebben.

In het laatste experiment, beschreven in *Hoofdstuk 5*, wordt onderzocht of leerlingen van de middelbare school zich bewust zijn van het positieve effect van tussentijds toetsen op het onthouden van informatie en of zij het gebruiken als leerstrategie tijdens het leren. Hiervoor vulden 321 Nederlandse leerlingen een korte vragenlijst in over studiegedrag en het gebruik van toetsen voor het leren. De resultaten komen overeen met de bevindingen bij universiteitsstudenten en laten zien dat leerlingen zichzelf zelden toetsen (bijv. overhoren). Ze zijn zich niet bewust

van het geheugeneffect van tussentijds toetsen. Ze gebruiken tussentijds toetsen eerder als diagnostisch instrument (bijv. om te kijken hoe goed ze de stof kennen).

Hoofdstuk 6 geeft een overzicht van de belangrijkste bevindingen van dit proefschrift, het gaat in op de belangrijkste beperkingen en het geeft een overzicht van de belangrijkste implicaties voor theorie en praktijk. Tevens worden de richtlijnen die in *Hoofdstuk 1* gepresenteerd werden herzien op basis van de bevindingen uit dit proefschrift en wordt er een nieuwe set richtlijnen gepresenteerd:

1. *Gebruik kort-antwoord vragen*
2. *Geef studenten de mogelijkheid de stof (alles) te herbestuderen met name wanneer de scores op de tussentijdse toets laag zijn*
3. *Toets de studenten herhaaldelijk*
4. *Toets dezelfde kennis op de afsluitende toets. Maak daarbij gebruik van isomorfe problemen*
5. *Creëer bewustzijn bij leerlingen voor de positieve effecten van tussentijds toetsen voor leren*

Zusammenfassung

Lehrkräfte verwenden Tests gewöhnlich als Bewertungs- oder Evaluationsinstrument. Gedächtnisforscher jedoch, haben entdeckt, dass das Schreiben einer Zwischenprüfung/Test ebenfalls einen starken Lerneffekt haben kann. Wenn zwischenzeitig ein Test geschrieben wird, werden die Informationen, welche im Test abgefragt worden sind, besser im Gedächtnis gespeichert. (Vgl. Rawson & Dunlosky, 2011; Roediger & Butler, 2011; Roediger, Putnam, & Smith, 2011). Dieser Befund wird als der Testing-effekt (oder auch oft Retrieval-effekt) bezeichnet. Der effekt beschreibt, dass das Abrufen von Informationen aus dem Gedächtnis, indem man Testfragen beantwortet, dazu führt, dass die Informationen besser im Gedächtnis gespeichert werden, als wenn man in der gleichen Zeit die Informationen einfach nur lesen würde.

Die meisten Studien die den Testing-effekt erforscht haben, sind unter Laborbedingungen mit einfachen Materialien, wie Wortlisten oder Wortpaaren, ausgeführt worden. Es gibt nur wenige Studien, die versucht haben den Testing-effekt in einem didaktisch relevanten Kontext zu erforschen. Die meisten dieser Studien sind dabei mit Universitätsstudenten durchgeführt worden. Diese Vorgehensweise ruft aber Fragen bezüglich der Effektivität dieser Lernstrategie für jüngere Schüler auf. Die Zielstellung dieser Dissertation ist deshalb zu erforschen, ob das Abrufen von Informationen aus dem Gedächtnis durch Tests eine effektive Lernstrategie für Schüler ist. In diesem Sinne tragen die Studien zur weiteren Erforschung des Testing-effekts bei Schülern bei.

In *Kapitel 1* dieser Dissertation wird eine allgemeine Einführung in die *New Theory of Disuse* (Bjork & Bjork, 1992) gegeben. Diese Theorie dient als Grundlage für unser Verständnis der kognitiven Prozesse, auf welchen der Testing-effekt aufbaut. Danach werden einige Richtlinien für die Erforschung und Implementierung des Testing-effekts im Unterricht präsentiert. Diese Richtlinien basieren auf den theoretischen und empirischen Grundlagen des Testing-effekts. Diese Richtlinien sind:

1. *Verwende Kurz-antwort Fragen*
2. *Gebe Schülern die Möglichkeit um (alle) Lernmaterialien erneut zu lesen*
3. *Teste die Schüler mehrmals*
4. *Teste dasselbe Wissen wie in der abschließenden Prüfung*

Kapitel 1 enthält außerdem eine Übersicht dieser Dissertation und der Forschungsfragen, welche wie folgt lauten: 1) Wie beeinflussen Zwischenprüfungen – im Gegensatz zum Verzicht auf Zwischenprüfungen – die Aufmerksamkeitsverteilung beim erneuten Lesen; und hat die Leistung der Zwischenprüfung einen Einfluss auf dieses Leseverhalten? 2) Führt das wiederholte Testen – mit erneutem Lesen – dazu, dass man Informationen besser auf einen Test eine Woche später anwenden kann und, wenn dem so ist, ist dem auch so, wenn die Aufgaben isomorphe Aufgaben sind? 3) Sind sich Schüler den positiven Effekten des Aufholens von Informationen aus dem Gedächtnis bewusst und benutzen sie diese Strategie im Unterricht?

Kapitel 2 präsentiert ein Experiment, das sich mit der ersten Forschungsfrage beschäftigt. Es wird untersucht, ob das Schreiben einer Zwischenprüfung einen Effekt auf die Aufmerksamkeitsverteilung während dem (erneuten) Lesen hat. Im Rahmen des Experimentes haben 56 Schüler einen Text gelesen. Nachdem sie den Text gelesen hatten, bekamen sie entweder einen Zwischentest über den Text und konnten danach den Text noch einmal lesen oder sie konnten den Text ein weiteres Mal lesen. Die Ergebnisse zeigen einen deutlichen Effekt des Beantwortens von Textfragen auf die Aufmerksamkeitsverteilung. Die Schüler, die zwischenzeitig getestet wurden, betrachten die Informationen die in der Zwischenprüfung abgefragt worden sind länger als die Schüler, welche keinen Zwischentest absolviert haben. Dies gilt vor allem für Fragen, welche die Schüler in dem Zwischentest nicht beantworten konnten. Außerdem zeigen die Ergebnissen das Schüler die Zwischenzeitig geprüft worden sind, viel bessere Ergebnissen aufzeigen auf einen Test eine Woche später.

Im zweiten Experiment, welches in *Kapitel 3* vorgestellt wird, wird untersucht, ob der Testing-Effekt auch auftritt, wenn die Schüler Prinzipien und Prozeduren anwenden müssen. Hierfür haben 38 niederländische Schüler einen Text über Wahrscheinlichkeitsrechnung entweder mehrmals gelesen oder den Text gelesen

und danach einen Test über Wahrscheinlichkeitsrechnung geschrieben. Die Ergebnisse zeigen, dass das Beantworten von Testfragen nicht nur dazu führt, dass man sich Fakten besser merken kann, sondern auch, dass man Prinzipien und Prozeduren besser anwenden kann. Mit anderen Worten, eine Zwischenprüfung hat nicht nur eine positive Auswirkung auf das Abrufen von Informationen aus dem Gedächtnis, sondern auch auf das Anwenden von diesen Informationen.

Im Gegensatz zur Studie in *Kapitel 3*, bei welcher die Fragen in Zwischen- und Endprüfung dieselben waren, wurde in den zwei Studien in *Kapitel 4* untersucht, ob Schüler dazu fähig sind ihr Wissen auf neue, isomorphe Problemen oder Situationen anzuwenden. In einer ersten Studie, lasen Schüler einen Text mehrmals oder sie lasen einen Text, beantworteten Fragen und lasen den Text noch einmal. Eine Woche später beantworteten alle Schüler eine Endprüfung mit denselben Anwendungsfragen und isomorphen Problemen. Die Ergebnisse zeigen dabei keine positiven Effekte auf Grund des Zwischentests. Ein Folgeexperiment, in dessen Rahmen die Schüler den Zwischentest ein zweites Mal beantworteten, zeigt jedoch, dass Zwischentests helfen die Informationen besser anzuwenden, sowohl auf dieselben Fragen als auch auf neue, isomorphe Fragen. Die Ergebnisse zeigen, dass Zwischenprüfungen dazu führen, dass Schüler Prinzipien und Prozeduren besser in neuen Situationen anwenden können, aber nur wenn die Schüler die Übungsaufgaben bei Zwischenprüfungen mehrmals bearbeitet haben.

Im letzten Experiment, welches in *Kapitel 5* beschrieben wird, wird erforscht, ob Schülern der positive Effekt von Zwischentests bewusst ist und ob sie diesen Effekt beim Lernen nutzen. Hierfür füllten 321 Schüler einen kurzen Fragenbogen über Lernstrategien und die Nutzung von Tests beim Lernen aus. Die Ergebnisse zeigen, dass Schüler selten Selbsttests zum Lernen anwenden; ein ähnliches Muster wie auch bei Universitätsstudenten. Sie wissen nichts über den Gedächtniseffekt von Tests und benutzen Tests eher als Diagnoseinstrument, z.B. um zu testen, wie gut sie den Schulstoff beherrschen.

Kapitel 6 gibt eine Übersicht über die wichtigsten Ergebnisse aus dieser Dissertation. Es zeigt die wichtigsten Einschränkungen der Studien auf und gibt eine Übersicht über die Anwendungen für Theorie und Praxis. Außerdem werden die Richtlinien, welche in *Kapitel 1* beschrieben sind, vor dem Hintergrund der Ergebnisse neu betrachtet und es wird ein neues Set von Richtlinien präsentiert:

1. *Verwende Kurz-antwort Fragen*
2. *Gebe den Schülern die Möglichkeit den Stoff (alles) nochmals zu lesen, vor allem wenn die Leistungen im Zwischentest nicht ausreichend war.*
3. *Teste die Schüler mehrmals.*
4. *Teste dieselben Informationen in der Endprüfung. Verwende dafür isomorphe Probleme.*
5. *Kreiere ein Bewusstsein für die positiven Effekte der Zwischentests auf das Lernen bei den Schülern.*

Curriculum Vitae



Kim Dirkx was born in Kerkrade, in the Netherlands, on 21 December 1985. She graduated in 2004 from pre-university education and went to the University of Maastricht, where she studied Health Sciences. During her Bachelor, she went to Zürich for nine months to study personality characteristics of highly gifted children. When she came back from Switzerland, she completed her Masters' in Mental Health Sciences and worked on a freelance basis as a trainer in the field of giftedness, and started working as research assistant for the VORCK-project at Maastricht University. After a few months, she was offered a position at the marketing department of the university, where she was responsible for school contacts and for organizing orientation activities for prospective students. At that time, she also started the Bachelor program to become a teacher in vocational education at Fontys University of Applied Sciences (short track), which gave her the opportunity to work as a trainer at the career service center of Maastricht University and at Fontys University of Applied Sciences. From 2010 onwards, she worked as a teacher in the Master Educational Sciences. She designed a course on assessment, was responsible for the course on "Learning and Instruction", and worked on her PhD-project "Optimizing adaptive learning through testing, diagnostic reflection, and learner control". The results of this project are described in this dissertation and are presented at several national and international conferences. She also organized several symposia (e.g., Earli Advanced Study Colloquium, 2012) for conferences, and went three months to the Leibniz Institute for Science and Mathematics Education (IPN) led by Professor Köller in Kiel to conduct one of her studies, and three months to the Department of Instructional Psychology of the University of Duisburg-Essen led by Professor Leutner.

After Kim has finished her PhD, she will continue to work at Fontys University of Applied Sciences as an assessment expert, where she has already been working for one day a week during the last year of her PhD. She is a practical person with a great deal of enthusiasm and inspiration.

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