Identifying opportunities to improve anticoagulation education at four medical schools by researching Dutch National Pharmacotherapy Assessment results, curriculum mapping and practical data and experience.

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Abstract

Background Preventable hospitals admissions related to medication (HARMs) are still far too common. Anticoagulation medication is one of the main causative agents of these preventable HARMs. Measures and recommendations in reducing HARMs caused by anticoagulation were in vain, as the number of these HARMs has shown no reduction in the past couple of years. Young "junior" doctors prescribe the most drugs and also make the most prescribing mistakes. The work performance of these junior doctors is linked to grade point average (GPA) at medical schools. Preliminary studies have shown that anticoagulation medication is a subject in which medical students show bad performance. Therefore, improving medical school performance in anticoagulation education and increasing anticoagulation scores could help to reduce preventable HARMs caused by anticoagulation drugs.

Objective This study aimed to identify opportunities to improve anticoagulation in medical schools by researching DNPA anticoagulation test scores of Erasmus University Rotterdam (EUR), Leiden University (LEI), Radboud Universiteit Nijmegen (RU) and the Vrije Universiteit van Amsterdam (VU), curriculum mapping of those same medical schools and practical prescription data and experience.

Method A triangulation of DNPA anticoagulation test scores, curriculum mapping and practical prescription data and experience has been performed. First, test scores of the DNPA were analysed to identify the higher and lower performing medical schools pertaining anticoagulation drug classes and topics. Second, a coarse analysis was made with data on curriculum mapping from previous studies at the four participating medical schools. Finally, prescription data and experience with the medical profession and anticoagulation education were obtained to provide an extra perspective.

Results Uni1 and Uni4 had the highest overall scores. Uni1 performed better than Uni2 and Uni3 with TAI questions. Uni4 had the best scores with VKA's. These were significantly higher than Uni2 and Uni3. Uni3 performed significantly worse than the other three medical schools with DOACs and LMWHs. For questions that combined drug classes Uni2 has scores that were significantly lower than the other three medical schools. Uni4 had the best scores in this 'drug class.' The coarse curriculum mapping showed that Uni3 has the biggest time period between anticoagulation education and the DNPA. Radboud had the smallest. Uni2 and Uni4 had time periods of similar length. Junior doctors don't remember much about anticoagulation education or the DNPA at their study. However, only positive opinions remained on the implementation of the DNPA and especially the reader. Prescription data and experience revealed that mistakes pertaining to double mediation, interactions, dosage and contra-indications can be made.

Conclusion Four opportunities to improve anticoagulation medication at medical school were identified. First medical schools need to cooperate and share knowledge about the way they teach in the highest scoring drug classes and subjects of the DNPA at their schools. Second, offering concise refresher lectures or assignments should reduce the time period between anticoagulation medication related subject matter and the DNPA and prevent knowledge from fading. Third, the DNPA reader is held in high regard and its availability should be announced earlier and more often, so students can review, learn, understand and apply the knowledge earlier and more often in their internships. Finally, DNPA subject matter and questions could be reviewed to research whether they lack certain subject matter or questions to better fit with the future professional practice.

Summary in Dutch

Achtergrond Er zijn hedendaags te veel voorkombare medicatie-gerelateerde ziekenhuisopnames (*"Hospital Admissions Related to Medication"* (HARM's). Antistollingsmedicatie speelt een grote rol in het veroorzaken van voorkombare HARMs. Ondanks aanbevelingen en maatregelen om deze HARMs te verminderen, blijft het aantal voorkombare HARMs die veroorzaakt worden door antistolling stabiel. Jonge 'junior doctors' maken de meeste voorschrijffouten én deze jonge artsen schrijven ook het meest voor. Van deze junior doctors wordt de werkvloerprestatie gelinkt aan schoolprestaties, met name aan het gemiddelde cijfer. Eerdere studies constateerde slechte cijfers op het gebied van antistollingsvragen op de Landelijke farmacotherapie eindtoets (FTE). Betere antistollingsonderwijs wat leidt tot betere cijfers op dit gebied zouden volgens de hiervoor genoemde verband moeten leiden tot betere werkvloer prestatie en uiteindelijk minder voorkombare HARM's met antistollingsmedicatie.

Doelstelling Dit onderzoek is verricht om mogelijkheden te identificeren om antistollingsonderwijs te verbeteren op geneeskundestudies door FTE antistollingsscores op de Erasmus University Rotterdam (EUR), Leiden University (LEI), Radboud Universiteit Nijmegen (RU) en de Vrije Universiteit van Amsterdam (VU), het in kaart gebrachte curriculum and praktisch voorschrijfdata en ervaring te analyseren.

Methode Een triangulatie is gebruikt om de vraag te beantwoorden. Ten eerste zijn de antistollingsscores op de FTE toetsen geanalyseerd om beter en slechter scorende universiteiten te identificeren. Dit werd gedaan voor geneesmiddelgroepen en onderwerpen. Daarna is een grove analyse uitgevoerd op de verzamelde data van het in kaart gebrachte curriculum van de vier voorgaande studies. Tot slot zijn klinische voorschriften bekeken en zijn er interviews gevoerd met jonge artsen.

Resultaten Over het algemeen hadden Uni1 en Uni4 de twee hoogste scores. Uni1 presteert beter dan Uni2 en Uni3 met TAI vragen. Bij VKA's is dit de Uni4. In deze geneesmiddelgroep scoort Uni4 beter dan Uni2 en Uni3. Leiden scoort lager dan de andere drie geneeskundefaculteiten met LMWH's en DOAC's. Voor deze twee geneesmiddelgroepen scoren Uni2 en Uni1 respectievelijk het beste. Het in kaart gebrachte curriculum laat zien dat in Uni3 de meeste tijd zit tussen de laatste antistollingslesmateriaal en het FTE. Uni1 heeft de kortste periode. Uni2 en Uni4 hebben een vergelijkbare 'pauzeduur'. De geïnterviewde artsen kunnen zich niet veel herinneren over het antistollingsonderwijs of het FTE tijdens de studie. Wel zijn de meningen positief over het FTE, met name over de FTE reader. Klinische voorschriften en ervaring suggereert dat fouten door dubbel medicatie, interacties, dosering en contra-indicatie mogelijk zijn.

Conclusie Er waren vier mogelijkheden geïdentificeerd om antistollingsonderwijs te verbeteren op de vier deelnemende geneeskundefaculteiten. Ten eerste staat samenwerking tussen de faculteiten centraal. Faculteit(en) die lager scoren op bepaalde antistollingsgeneesmiddelgroepen en onderwerpen kunnen wat leren van faculteiten die het beste scoren op diezelfde onderwerpen. Ten tweede moet een lange "droogte" aan antistollingsmedicatielessen worden verkort door het aanbieden van bondige opfriscolleges en/of opdrachten. Ten derde wordt de farmacotherapie eindtoets reader foor zijn duidelijkheid en overzichtelijkheid erg hoog in het vaandel gehouden en moeten de faculteiten geneeskundestudenten eerder introduceren een vaker een reminder geven dat het er is, zodat ze vaker met de leerstof in aanraking komen. Tot slot, FTE studiemateriaal en toetsvragen met betrekking tot antistolling zouden opnieuw geëvalueerd kunnen worden om te kijken of deze een update nodig hebben om beter aan te sluiten op de praktijk.

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2. Introduction/Background

One of the promises a Dutch doctor must make upon receiving his/her medical license and one of the more famous quotes in the medical world comes from the Hippocratic Oath: “First, do no harm.” (1) But what if the medication a physician prescribes could be the exact cause of harm to a patient? In a study done by Leendertse et al. it was discovered that 5,6% of all unplanned hospital admissions in 21 hospitals in a period of forty days were medication related. Nearly half (46,5%) of these hospital admissions related to medication (HARMs) were potentially preventable. (2) HARMs bring a big burden to patient, as they bring adverse reactions resulting in potential consequences varying from hospital admissions to disability to death. Furthermore, these preventable HARMs have a significant impact on the national health budget. (3) These preventable costs also limit budget flexibility in other areas of health care and could potentially repress the use of other (more expensive) treatments

Anticoagulation medication is one of the more prominent medication groups mentioned as causative agents for preventable HARMs. (2,4) Since the publication of the study by Leendertse et al. multiple recommendations have been made to decrease hospital admissions related to medication (HARMs). (5) Despite these measures, the prevalence of preventable HARMs in anticoagulation medication seemed to stay stagnant (2009-2013). (5) This showed that problems with preventable HARMs pertaining to anticoagulation medication persist and more measures must be taken to reduce these HARMs, especially when the amount of anticoagulation prescriptions has seen a steady increase in the last couple of years. (6)

Prescription errors are mentioned frequently as causes of preventable HARMs. (2,4,7) A study by Dornan et al. revealed which doctors make the most prescribing mistakes. Doctors in their first or second year after graduation are called junior doctors and they are almost twice as likely to make prescription errors as specialist level doctors. (8) Furthermore, these junior doctors make the majority of drug prescriptions. (9) Decreasing prescribing mistakes made by this group of doctors could go a long way to reduce preventable HARMs caused by anticoagulation medication. Two studies done by Carr et al. revealed that work performance of junior doctor could be tied to academic performance. They determined that especially students with a good grade point average (GPA) showed better overall performance as junior doctors. (10,11) Therefore, one can hypothesis that students that have higher scores in anticoagulation subjects will make less anticoagulation prescription errors in the medical practice, leading to lower amounts of preventable HARMs pertaining to anticoagulation medication.

One of the ways to test medical students on their knowledge of medication is a test used by medical schools in the Netherlands called “Dutch National Pharmacotherapy Assessment” (DNPA). It is a test developed by every Dutch (eight to be precise) and three Belgian medical schools focusing on medication safety. The medical knowledge tested on in the DNPA is derived from a list of drug groups causing the majority of preventable adverse reactions. (12) The test consists of sixty multiple choice questions pertaining to these drug groups and general subjects. With a passing grade of 85,0%, the bar to pass this test is set high and one could say that passing the test show that medical students have sufficient pharmacological and pharmacotherapeutic knowledge to safely prescribe the list of drugs tested on. An overview of the drug groups and subjects can be found in table 1.

Table 1 Subjects covered by the DNPA (13)

Drug groups	A.	Analgesics
	B.	Anticoagulation
	C.	Cardiovascular Drugs
	D.	Antidiabetics
	E.	Antidepressants
	F.	Benzodiazepines
	G.	Antibiotics
General subjects	H.	Pharmacokinetics
	I.	Drug Allergies
	J.	Laws & Regulations
	K.	Proper Drug Usage
	L.	Pregnancy and Lactation

Preliminary research has been done by four predecessors on the anticoagulation part of the DNPA in four different medical schools in the Netherlands. These four medical schools were the Erasmus University Rotterdam (EUR), the Leiden University (LEI), the Radboud University Nijmegen (RU) and the Vrije Universiteit of Amsterdam (VU). Preliminary research in these four medical schools has shown suboptimal scores in anticoagulation questions compared to other drug classes. (14–17) Three of the four studies have also shown that the questions are of adequate quality. (15–17) As the same test versions were used in all four schools, it can be derived that the question quality in all four schools was of adequate quality and the cause of the suboptimal scores could lie in other areas. Up until this date no analysis has been made comparing the anticoagulation question scores in the four medical schools.

This study aimed to identify opportunities to improve anticoagulation in medical schools through a triangulation of DNPA test results, curriculum mapping and practical experience and data.

3. Method

This retrospective, observational cohort study was designed to compare the anticoagulation scores on the DNPA in four medical schools to identify which medical school performed best in the different drug classes and subjects.

To achieve this aim, several aspects have been studied. First and foremost, a quantitative analysis of the anticoagulation scores on the DNPA has been used to determine which medical school performed best in certain drug classes and/or subjects. Secondly, the curriculum mapping of the four medical schools have been compared to each other. Furthermore, anticoagulation prescribing mistakes made in June 2021 at the Erasmus Medical Centre have been researched to see if some kind of link could be made to the DNPA results. Finally interviews of below specialist level doctors have been conducted to add an extra perspective.

For this study two permissions had to be taken into account. The overarching study pertaining the test results has been granted by the Ethical Review Board (ERB) of the Dutch Association of Medical Education (NVMO). Conducted interviews were viewed as follow up to student questionnaires from preliminary studies and therefore acknowledged as an extension of the permission granted by the ERB. The dataset with prescriptions made at the Erasmus MC in June 2021 was provided by a yet to be published study, BAS-E-RROR. Permission for this study has been granted by the Medical Ethics Committee (METC) from the Erasmus MC. All existent data has been received anonymously and new data has been made anonymous and was stored on a secured “V-schijf” on the Erasmus MC server.

3.1. Quantitate analysis of anticoagulation questions.

3.1.1. Data acquisition and processing

To analyse the anticoagulation scores, all test data used in prior research has been collected and converted, as shown in figure 1. First, 689 exams from thirteen different test moments at EUR were collected in the period from October 2018 until March 2020. One test was incomplete and excluded from the analysis and exam data included the first made test since the introduction of the DNPA Second, 405 exams from thirteen different test moments at LEI were collected in the period from September 2019 until August 2021. For EUR and LEI, test data included the first DNPA conducted at those medical schools. Third, 645 exams from nineteen different test moments at RU were collected in the period from September 2018, 4 years after the test was implemented in 2014, until March 2020. Finally, 625 exams from 27 different test moments at the VU were collected in the period from August 2019, 4 years after the test was implemented in 2015, until April 2022. At the VU, four exams were incomplete and excluded from the analysis.

All together this resulted in 2359 exams of which each exam had nine anticoagulation questions, resulting in 21.231 question answers that were analysed. However, every test is made significantly worse in the “start-up period” before reaching consistent test scores, like drugs before reaching steady state. Therefore, a secondary analysis in which the first few test moments of EUR and LEI were excluded was done. Unfortunately, no literature could be found that revealed the number of conducted test moments or months needed before test scores reach steady state. To account for the start-up period, the first five tests at the EUR and LEI were excluded from the secondary steady state analysis, like the number of half-lives needed for a drug plasma concentration to reach steady state. This accounted for 138 exams from EUR and 165 exams for LEI, which were excluded for the steady state analysis.

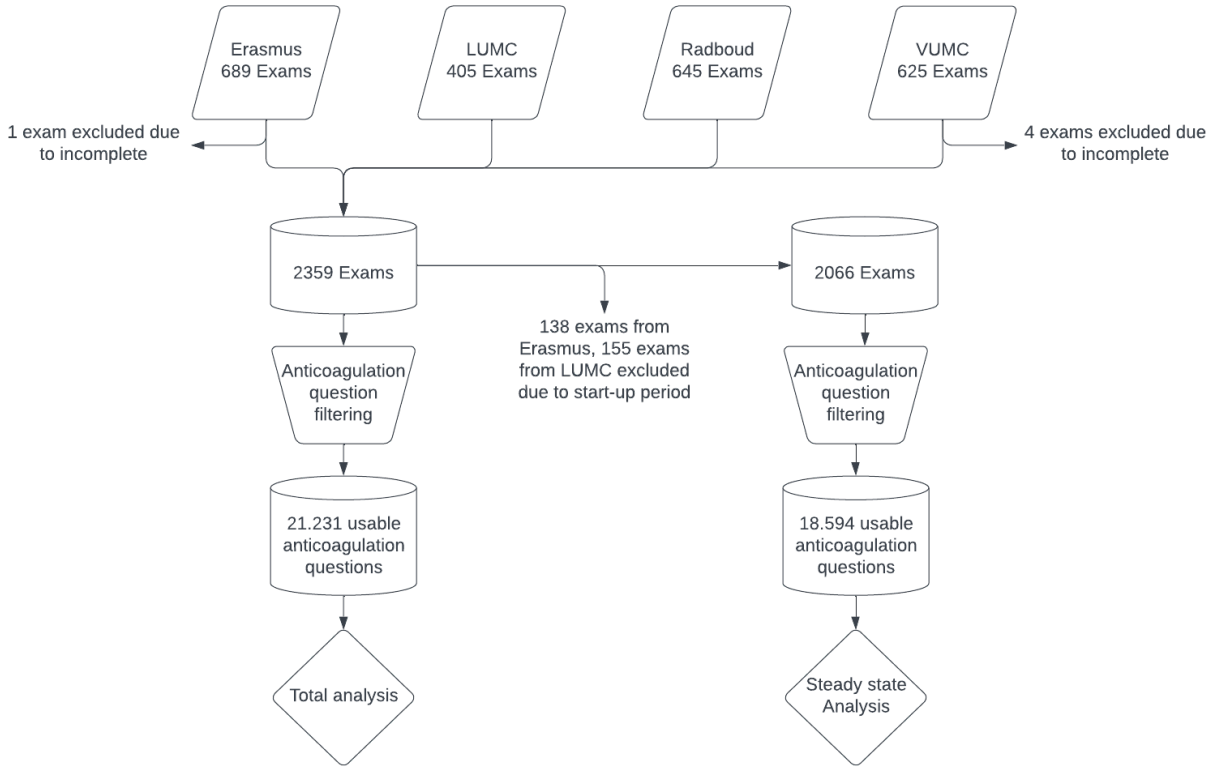

Figure 1 Data acquisition and processing.

3.1.2. Categorizing questions

To compare the answers and scores, test versions of each medical school were collected and questions on these versions were compared. Luckily, the four medical school used the same questions in the DNPA but not all used the same question name in their coding. To account for this, every question was copied into an excel file. Questions were then matched to each other based on the question, answer and incorrect multiple-choice answers.

However, it was noteworthy that there were inconsistencies with the test versions from one of the four medical schools. The question codes in the test data did not match the question codes on the test versions. To account for this, every question code in the supplied test data were matched with the same question codes from the test versions of either their own medical school or the other three medical schools. The ten test versions were then recreated. Questions in the original test data have been coded with a very unique sequence consisting of letters, numbers and dots. Therefore, a precise match with the question code could (almost) certainly guarantee that those are the correct questions and test versions used in the real exam.

Next, the questions were assessed on three different levels. First the question was categorized into one of four drug classes; secondly, the question was categorized into a topic and finally, questions were categorized into required competence level according to Bloom's taxonomy of educational purposes. Table 2 and 3 cover the drug classes and topics used in the analysis.

Table 2 Anticoagulation Drug classes in the DNPA.

Drug Classes
Thrombocyte aggregation inhibitors (TAIs)
Vitamin K antagonists (VKAs)
Low molecular weight heparins (LMWHs)
Direct oral anticoagulants (DOACs)
Combination of drug classes (Combi)

Table 3 Anticoagulation Topics in the DNPA.

Topics
Interaction
Indication
ADME
Mechanism of action
Antidote
Dosage
Drug properties
Bridging
Discontinuation of Drug
Platelet Life
Side Effects

The third level focused on the competence level needed to answer the question. Bloom and colleagues developed a model to classify educational learning objectives. This framework consists of six levels based on complexity and specificity. This framework is pictured in figure 2.

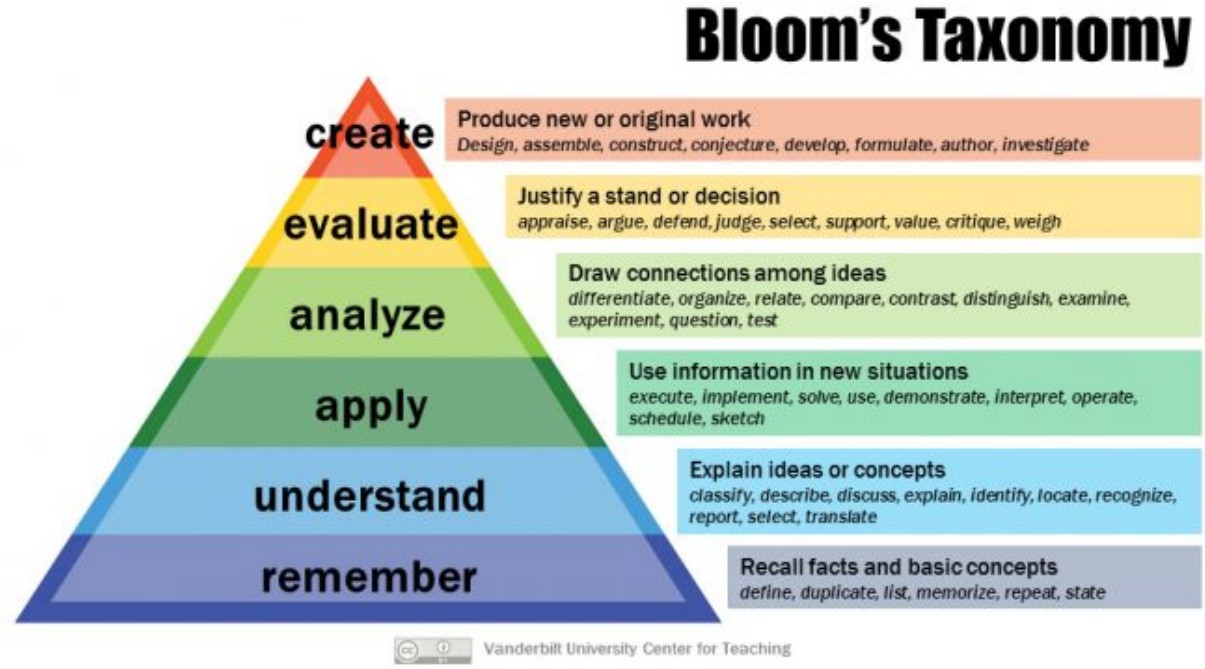

Figure 2 Bloom's taxonomy of educational purposes. The higher the level, the more complex this level is. (18)

For this study only the first three levels of this framework were reached in the questions. To determine what competence level was needed to answer a question, the first three levels of Bloom's taxonomy had to be defined. The definition of the first three levels used in this study is depicted in table 4.

Table 4 Definition of the first three levels of Bloom's taxonomy used in this study

Bloom's taxonomy level	*Definition*	*Question example*
Remember	The student can recall information and concepts pertaining drugs, as descripted in the reader. For example, the student can name the indications or antidote used for phenprocoumon.	What is a correct indication for clopidogrel as monotherapy. (Answer: first choice as secondary prophylaxis after a TIA)
Understand	The student can understand and explain certain ideas or concepts of the basics of haematology and explain how a drug works in this process. From this, a student can specify if a drug is or is not qualified depending on patient characteristics, such as age, sex, comorbidities, co-medication, etc.	A patient receiving treatment with phenprocoumon has an INR >7. There are no indications pointing to a bleed. Which of the following antidotes can be best used to decrease the bleeding risk (Answer: administering vitamin K for a few days)
Apply	With knowledge of the first two levels a student can apply their knowledge and select a drug, out of a list of options, that is best qualified for a patient with certain patient characteristics, such as age, sex, comorbidities, co-medication, etc.	A 65-year-old man with hypertension and is hypersensitive to acetylsalicylic acid. He presents symptoms of angina pectoris. His current medication is Enalapril 1 dd 20 mg, hydrochlorothiazide 1 dd 12,5 mg, simvastatin 1 dd 40 mg, metoprolol 1 dd 100 mg. Which of the following drugs is best qualified as cardioprotective measure for angina pectoris for this patient. (Answer: clopidogrel)

3.1.3. Data analysis

Statistical analysis was performed with IBM SPSS Statistics version 28.0.1.0. As every question was answered correct or incorrect, the data was categorized as categorical data. To analyse test data, a chi-square test was utilized on all drug classes to see if there were statistical discrepancies between the four medical schools. However, a statistically significant difference did not mean the determined outcome also had significance in the real world. To determine whether a statistical difference had practical significance, a closer look into the strength of association was needed. For the strength of association IBM SPSS Statistics calculated the Cramer's V and Phi values. The bigger these values, the stronger the association between the scores and the medical schools in which the questions were made. The values held for strength of association are categorized in table 5. For analyses between two medical schools the Phi value was used; for analyses between three or four medical schools the Cramer's V value was used. (19)

Table 5 Strength of association. (20)

Cramer's V and Phi Value	Strength of association
>,25	Very strong
,15 - ,25	Strong
,10 - ,15	Moderate
,05 - ,10	Weak
,00 - ,05	Absent or very weak

According to this strength of association table, Cramer's V or phi values of drug classes under ,100 were considered not practically significant, as this meant that the practical significance was weak, very weak or absent. For drug classes in which the Cramer's V or phi value surpassed the threshold of ,10 further chi square tests were done in multiple levels. First, a look was given in the several

topics and different competence levels in each of the different drug classes. Second, if the determined Cramer's V of phi value held at least moderate significance, multiple chi square tests, of which in each test one of the four medical schools was omitted, was performed. If one of these tests showed no practical significance, then it was determined that the omitted medical school is the one causing the discrepancy in question scores. Finally, chi square tests were performed between all four medical schools in a one vs. one format to determine which two medical schools showed the biggest association between medical school and test scores.

3.2. Curriculum mapping

For the next step in this study, data was used from preliminary studies that have already performed curriculum mapping of the medical study in the four medical schools. Analysis of available data from the curriculum mappings revealed that not all four preliminary studies have performed curriculum mapping equally thorough. In the creation of two of the four curriculum mappings similar methods have been used. Both searched coursebooks on keywords pertaining anticoagulation drugs and subjects and noted important lectures or assignments and these were mapped accordingly. (15,17) The third preliminary study made use of a database, the "Curriculum Information System" (CIS), in which data pertaining to all classes, practical assignments and self-study assignments taught in the bachelor or master could be found. Titles and sometimes a small description of the education content were available in this database. The same keywords were used for a broad search on potentially educational moments and lecturers were contacted to provide additional information. Important educational moments were then noted and mapped. (16) The final predecessor did the most extensive curriculum mapping. In this study, in addition to the steps taken by previous researchers, all relevant subject matter was manually combed through. Even lectures and text books were viewed online or in person and all anticoagulation hits were categorized in several categories. (14)

The four curriculum mappings have not been done in the same depth and method. Therefore, it was difficult to make an exact and precise comparison between the four medical schools. However, a broad approach was used to compare the four medical schools. All four curriculum mappings had a somewhat similar timeline in when anticoagulation education was given relative to the DNPA in the six-year program. Accordingly, a course analysis was made on where the focus on anticoagulation education was located in the timelines.

3.3. Practical data & experiences

3.3.1. Prescription data

To analyse prescription data a dataset was acquired from a yet to be published study called BAS-E-RROR. In this dataset all 145.574 clinical prescriptions at the Erasmus Medical Centre in the month of June 2021 were collected. In this dataset all prescriptions pertaining anticoagulation medication were labelled according to the drug classes. Appendix A shows the list of drugs and brand names used in the search for anticoagulation medication in the prescription data. Anticoagulation medication was either categorized in the four main drug classes of the DNPA or "enzymes." Furthermore, in this dataset all mistakes that the hospital pharmacy discovered before the drug was administered to the patient were noted with the possible estimated consequences. The possible estimated consequences were categorized according to the Medication Errors Index of the National Coordinating Council for Medication Error Reporting and Prevention (NCC MERP). The NCC MERP Index for Categorizing Medication Errors is shown in figure 3. As all prescription errors were intercepted by the hospital pharmacy before the drug reached the patient, in reality, all prescription errors in this dataset should fall into category B: an error occurred, but the error did not reach the patient. However, for this study the researcher estimated the potential consequence if the prescription errors in this dataset did reach the patient. These consequences could hypothetically fall

between category C, an error that did not cause patient harm, and category I, an error that may have contributed to or resulted in the patient's death.

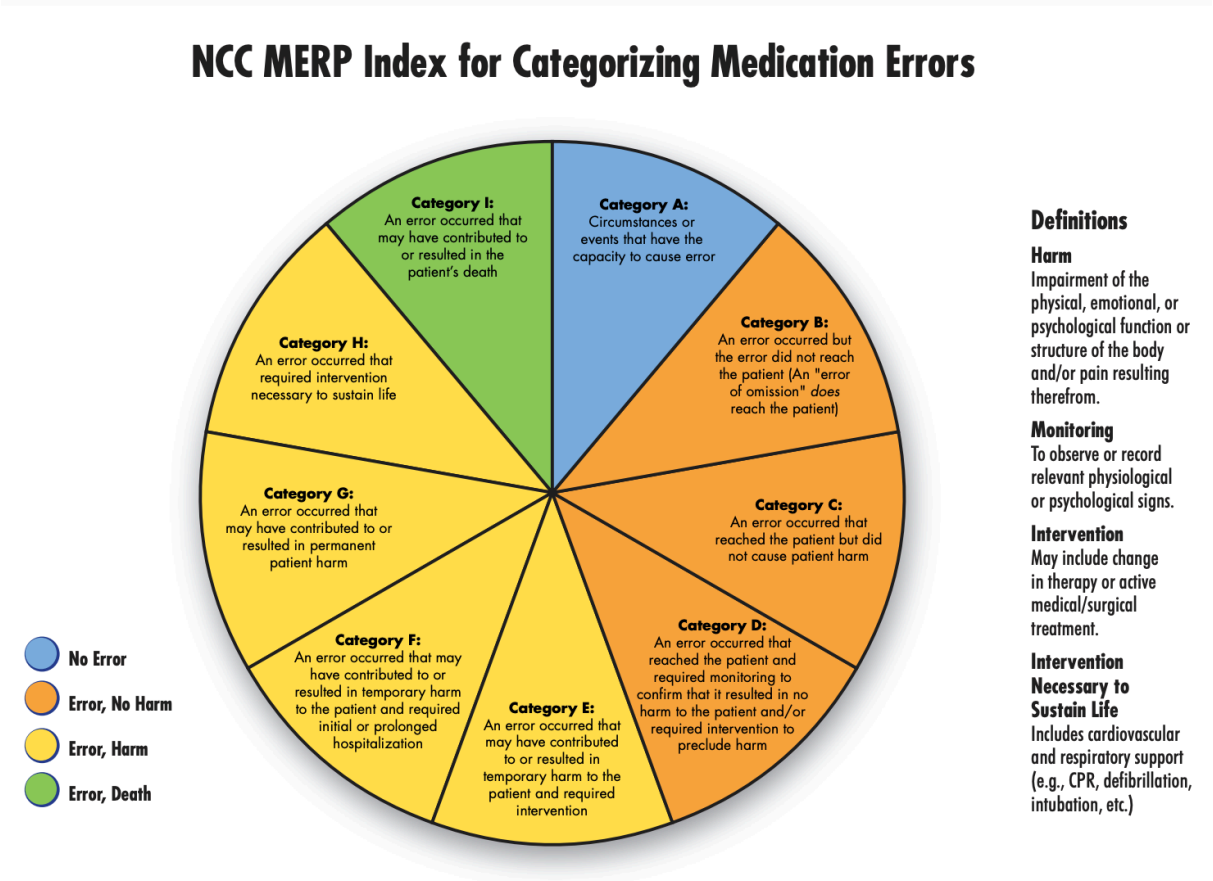

Figure 3 NCC MERP Index for Categorizing Medication Errors. (21)

3.3.2. Interviews with non-specialist level doctors

As an extension to the prescription data, seven non-specialist doctors have been interviewed on their experiences with anticoagulation medication. Three of the seven interviewees were doctors that already have extensive doctor career (ten years' experience). The other four interviewees were junior doctors in their second or third year after graduation. An initial interview guide was made and used in the interviews with the three more experienced doctors. The interview guide was than amended and used in the interviews with the other four doctors. After the interviews were conducted, an extra question was sent through text or e-mail to inquire about the mistakes they have seen or experienced. Four of the interviewees replied to the extra question. Interview answers have been transcribed in word and answers were noted in excel to look for recurring themes.

4. Results

4.1. Pharmacotherapy Exam

Overall, anticoagulation questions were answered 84,8% correctly. Of the four medical schools, RU scored the highest with 88,2%, VU scored the second highest with 87,5%, EUR scored the third highest with 81,7% and LEI scored the lowest with 80,8%. After disregarding the test scores from the first five tests at LEI and LEI, both test scores rose to 82,7% and 82,2%, respectively.

Analysis of the different drug classes all chi-square tests between four medical schools showed a statistical significance of <0,001. The results of this analysis and all subsequently results, performed chi square tests and tables are shown in appendix B. However, not all statistically significant differences are of practical significance. To determine if the practical significance was sufficient enough the Cramer's V value had to be of moderate value (at least 0,100). Cramer's V values of the TAIs showed that the statistically significant difference did not hold practical significance in both the primary and secondary steady state analysis. However, for the integrality of the analysis, the TAIs questions were analysed as well. Cramer's V values of VKAs only showed a practically significant difference when tests from the start-up period were included. However, for the LMWHs, DOACs and Combination drug classes, a practically significance could be found with or without the start-up period from EUR and LEI.

4.1.1. Thrombocyte aggregation inhibitors

In the TAIs, RU had the highest scores with 90,4%. VU had the second highest performance with 86,7%. LEI and EUR placed third and fourth on this ranking with scores of 83,5% and 82,9% respectively. After reaching steady state the last two scores increased to 84,8% for EUR and 84,7% for LEI. Both chi square test showed weak practical significance as both Cramer's V values fell between ,050 - ,100.

Even though the chi square test showed that the association between test scores and medical schools was weak, it could be noted that moderate association could be found between medical schools, when all test data was analysed. In the one versus one analysis, moderate association could be found in the comparison between RU & EUR and RU & LEI. Other comparisons resulted in associations varying from weak to absent. Test data after reaching steady state showed that the triplet of EUR, LEI and VU showed no statistically significant difference. The addition of RU was the only factor that caused a statistical difference. This was confirmed by the one versus one analysis, in which every comparison of RU with one of the three other medical schools resulted in a weak association. A closer look at the different subjects revealed four subjects with strong to very strong association between subject score and medical school before and after reaching steady state. These were mechanism of action, dosage, discontinuation of drug and platelet life. In three of the four subjects a clear distinction could be found between two duos, namely EUR & LEI and RU & VU. The latter duo scored significantly higher in dosage, drug discontinuance and platelet life. EUR scored significantly lower with questions about mechanism of action than the other three medical schools, especially after steady state was reached.

Analysis of the competence level showed that the biggest differences could be found within the questions on the level of understand. In this category the same distinction between the two duos could be found as well. However, after reaching steady state the difference between LEI and VU became less practically significant. What was noteworthy was that questions at the 'understand' level had higher scores than questions at the 'remember' level, except for EUR.

4.1.2. Vitamin K antagonists

In the drug group of the VKAs, VU had the highest overall scores of 88,2%. RU came next with 87,9%. EUR scored 81,0% before and 82,4% after reaching steady state. For LEI this was 80,2% and 83,3% respectively. The Cramer's value of ,102 suggests that this difference is moderately significant. After excluding tests in the start-up period, this practical significance dropped to weak (,076).

Due to the slight increase in scores from EUR and LEI, the practical significance disappeared after reaching steady state. In the VKAs a clear split was observed between two pairs, namely EUR & LEI with the lower scores and RU & VU with the higher scores. This was witnessed in the four comparable chi squared tests in which each of the three medical schools were compared to each

other. Analysis of the several subjects revealed that three subjects stood out with the highest practical significance before and after reaching steady state. These subjects were antidote (Cramer's V values of ,212 and ,251) and bridging (Cramer's V values of ,252 and ,187) and to a lesser extent interactions (Cramer's V values of ,125 and ,102). Analysis of the scores and multiple one versus one chi square tests revealed the medical schools that caused the big discrepancies in. For the first two subjects the biggest differences could be determined between EUR and VU, as these comparisons showed the highest phi values. For Interactions, the comparison between EUR and RU had the highest phi value.

Analysis of the competence level of the questions showed that 'remember' questions did not have a practical significant difference. Questions of 'understand' showed a moderate practical difference. Comparable with the overall scores, the difference in scores could be classified in two duos, with EUR and LEI having the lower scores and RU and VU having the higher scores. This was apparent in the one versus one analysis, where the only practical significant differences could be found between the two duos. In this drug class, 'remember' questions had higher scores than 'understand' questions, except for RU.

4.1.3. Low molecular weight heparins

In the second drug class of the LMWHs, EUR had the highest scores with 90,1% before and 93,3% after reaching steady state. Next came VU and RU with scores of 89,0% and 86,0% respectively. What was noteworthy was that the overall scores in LMWHs from LEI suffered a decline from 75,4% to 74,0%. As a consequence, the increase in Cramer's V value in this drug class came as no surprise. The multiple 3 medical schools chi square tests revealed that LEI was the most main cause for the practical significant difference in this class. In both before and after steady state analysis it could be determined that the difference between EUR, RU and VU held weak to no practical significance. Only after adding LEI did the Cramer's V value of the chi square test surpass the threshold of 0,100.

Of the four subjects, two stood out with strong association. These two subjects were antidote with Cramer's V values of ,234 and ,212 and drug properties with Cramer's V values of ,205 and ,163. Zooming in on the one the one versus one chi square tests in these two subjects it could be determined what caused these discrepancies in scores. For antidote it was shown that LEI scores significantly lower than the other three medical schools. Especially when comparing the scores between LEI and RU & VU before and after reaching steady state. For EUR versus LEI this difference was only significant before reaching steady state, probably due to the few question answers present in EUR (N=6). For drug properties this difference was less present. Here the LEI scored slightly higher and EUR scored slightly lower. Therefore, only VU kept the high significance after reaching steady state.

Analysis of the competence level showed that the difference was mainly caused by the 'remember' questions. The multiple three medical school chi square test revealed that the triplet of EUR, RU and VU showed weak to no practical significance before and after reaching steady state. After further investigation of the one versus one analysis, it became clear that the difference between LEI & RU and LEI & VU were the main culprits for the disparity in this competence level. For LMWHs, it was also noteworthy all participating medical schools scored higher on questions that required a higher level of competence. 'Understand' questions had higher scores than 'remember' questions.

4.1.4. Direct oral anticoagulants

In the DOACs a similar trend could be observed. EUR had the highest scores as it scored 88,6% before and 89,6% after reaching steady state. RU and VU came next with scores of 84,7% and 82,4% respectively. Finally, LEI scored comparatively low with scores of 66,7% before and 63,1% after

reaching steady state. Like with the LMWHs, the Cramer's V value increased slightly after reaching steady state.

Of the four subjects the cause could again be found in antidote and drug properties. Numbers before reaching steady state showed Cramer's V values that reached strong and moderate significance for antidote and drug properties respectively. The other two subjects, ADME and mechanism of action showed no statistical difference. Analysis of the antidote subject revealed that EUR, LEI and RU have scores that had no significant practical difference, as seen in the multiple three medical school chi square test. Only triplets with VU present showed moderate to strong practical significance. The one versus one analysis showed that the strongest difference was between LEI and VU with a very high phi value of ,392 between these two medical schools. In addition, there was a strong association of difference in the comparison between LEI and EUR; and EUR showed a moderate difference with VU. After reaching steady state the main difference was that all test answers for LEI were not included, as all the data on these questions were derived from the start-up period. So only three medical schools remainwd in this subject. The only practically significant difference that remained, was between EUR and VU.

The next subject, drug properties, EUR, RU and VU had percentages that resembled each other, with scores of 64,5%, 67,7% and 64,5% respectively. LEI is scored the lowest with 52,5%. The multiple three medical school chi square tests showed that only triplets where two out of the three were LEI and RU showed statistical and practical importance. The one versus one analysis also revealed the same, as the phi value of ,176 between LEI and RU is the highest. In addition, the analysis also showed that the comparison between VU and LEI resulted in a moderate practical difference. When steady state was reached, the only significant differences that were maintained are between LEI and RU and LEI and VU. However, it was noteworthy that all four medical schools scored rather low in this subject, as none of the scores were higher than 67,7%.

In this drug class, the understand questions were more responsible for the difference between the four medical schools compared to the remember questions. The multiple three medical school chi square test only showed significant differences when both LEI and RU were present in the triplet. Therefore, the cause for the significant difference could mainly be contributed to the difference between LEI and RU, as shown in the highest phi values in the one versus one analysis. The scores for the competence level were similar to VKAs in the fact that every participating medical school reached higher scores on questions on the level of 'remember.'

4.1.5. Combination of drug classes

Questions pertaining to the combination of drug classes showed that VU had the highest scores with 89,2%. Before reaching steady state, ranked second to last in order were RU, LEI and EUR with scores of 87,7%, 87,7% and 72,7%. When steady state was reached, this ranking changed to LEI, RU and EUR with scores of 88,1%, 87,7% and 72,1% respectively. This drug class held the highest Cramer's V value and it slightly increased as well after reaching steady state.

Analysis of the different subjects before reaching steady state showed that ADME had the highest practical significant difference before and after reaching steady state with Cramer's V values of ,343 and ,393 respectively. However, it was of note that LEI had 0 questions in this subject. Further analysis of the differences in this subject revealed that EUR scored fairly low with 51,3% and 45,6% compared to RU and VU with 82,6% and 84,0% respectively. This could also be seen at the very strong phi values in the one versus one analysis.

The other subject that stood out is indication. A similar situation could be seen when comparing EUR to the other three medical schools. Before and after reaching steady state LEI scored lower with 76,0% and 75,1% compared to LEI with 85,0% and 84,3%, RU with 86,2% and VU with 86,9%. The chi

square test of the multiple three medical school test verified this result, as the triplet of LEI, RU and VU showed no statistical difference before and after reaching steady state. Analysis of the one versus one analysis showed phi values that were consistent with the test scores, as the comparison between EUR and VU had the highest disparity in test scores and phi value.

Analysis of the competence level in the final drug class revealed the biggest disparity in test scores in remember and apply questions. EUR scored significantly lower than the other three medical schools with remember questions. This was also apparent in the multiple three medical school chi square test, as there were no significant differences in the triplet of LEI, RU and VU. The one versus one showed the same. The only practical significant differences could be found between EUR and one of either of the three other medical schools. For the apply questions, one medical school stood out with comparatively higher scores and that was VU. Like the remember questions, only one medical school was different than the other three. However, in contrast to EUR, VU had the higher scores on this competence level. LEI and RU had a predictable score trend when the competence level of questions increased: the scores decreased. EUR and VU had the highest scores in 'understand' questions and lowest scores in the 'apply' questions.

4.1.6. Summary of test results

Tables 6 and 7 provides an overview of the test scores from the primary and secondary steady state analysis. The table depicts the relevant drug classes and subjects with the higher and lower scoring schools. If a medical school did not have any relevant differences with any of the medical school, it is not shown in the table.

Table 6 The lower scoring and higher scoring medical schools in drug class, subject and competence level in the primary analysis.

Drug Class	*Subject*	*Lower scoring medical school(s)*	*Higher scoring medical school(s)**
TAI	Overall	EUR, LEI	RU
	Mechanism of action	EUR	LEI, (RU), VU
	Dosage	EUR, LEI	(RU), VU
	Drug discontinuance	VU	EUR, LEI, (RU)
	Platelet life	EUR, LEI	RU, (VU)
	Remember**		
	Understand	EUR, LEI	(RU), VU
VKA	Overall	EUR, *LEI*	RU***, (VU)
	Interaction	EUR, LEI	RU
	Antidote	EUR	LEI, RU, (VU)
	Bridging	EUR	VU
	Remember**		
	Understand	EUR, *LEI*	(RU), VU***
LMWH	Overall	LEI	(EUR), RU, VU
	Antidote	LEI, EUR	(RU), VU
	Drug properties	*EUR,* LEI	(RU), VU***
	Remember	LEI	EUR, RU, (VU)
	Understand***		
DOAC	Overall	LEI	(EUR), RU, VU
	Antidote	LEI	RU, (VU)
	Drug properties****		
	Remember	LEI	VU
	Understand	LEI	RU
Combination of drug classes	Overall	EUR	LEI, RU, (VU)
	Indication	EUR	LEI, RU, (VU)
	ADME	EUR	RU, (VU)
	Remember	EUR	LEI, (RU), VU
	Understand**		
	Apply	EUR, LEI, RU	VU

** Between brackets shows the school with the biggest practical significant difference(s).*
*** None of the one versus one analysis showed practical significant differences.*
**** Only shows practical significant difference with the medical school written in **italics**.*
***** All four medical schools need improvement in this subject: none scored higher than 67,7%.*

Table 7 The lower scoring and higher scoring medical schools in drug class, subject and competence level in the secondary steady state analysis.

Drug Class	*Subject*	*Lower scoring medical school(s)*	*Higher scoring medical school(s)**
TAI	Overall**		
	Mechanism of action	EUR	LEI, (RU), VU
	Dosage	EUR, LEI	(RU), VU
	Drug discontinuance	VU	LEI, (RU)
	Platelet life	EUR, LEI	RU, (VU)
	Remember**		
	Understand	EUR, *LEI*	(RU), VU***
VKA	Overall**		
	Interaction	EUR, LEI	RU
	Antidote	EUR	LEI, RU, (VU)
	Bridging	EUR	LEU, RU, (VU)
	Remember**		
	Understand	EUR, LEI	RU
LMWH	Overall	LEI	(EUR), RU, VU
	Antidote	LEI	(RU), VU
	Drug properties	LEI	VU
	Remember	LEI	RU, (VU)
	Understand***		
DOAC	Overall	LEI	(EUR), RU, VU
	Antidote	EUR	VU
	Drug properties****		
	Remember**		
	Understand	LEI	RU
Combination of drug classes	Overall	EUR	LEI, RU, (VU)
	Indication	EUR	RU, (VU)
	ADME	EUR	RU (VU)
	Remember	EUR	LEI, (RU), VU
	Understand**		
	Apply	EUR, RU	VU

** Between brackets shows the school with the biggest practical significant difference.*
*** None of the one versus one analysis showed practical significant differences.*
**** All four medical schools performed good in this subject, none scored lower than 95,3%*
***** All four medical schools need improvement in this subject: none scored higher than 67,7%.*

4.2. Curriculum scan

For the next step, a coarse overview was made with the curriculum mappings done by the preliminary studies. A timeline of the bachelor is shown in figure 4. This timeline is a very concise summary of the periods in which anticoagulation education was given as a main or secondary subject. A more detailed overview of the timeline with the course names in which anticoagulation teaching moments were present can be found in appendix C.

The focused periods of anticoagulation teaching moments in the bachelor phase revealed a different distribution throughout the first three years of the curriculum. At EUR the subject was primarily taught during the first year of the bachelor and near the end of the bachelor. At LEI assignments and lectures where anticoagulation education was taught as a primary subject were focused in the second year. Throughout the first and third year of the bachelor, anticoagulation teaching moments were, however in a lesser role, also present throughout several subjects. For RU similar observations were made. However, teaching moments seemed to be present in a lesser role in other courses. At VU anticoagulation education seemed to be focused near the end of the bachelor, with anticoagulation mentioned as a secondary focus in few subjects in the first and second year of the bachelor.

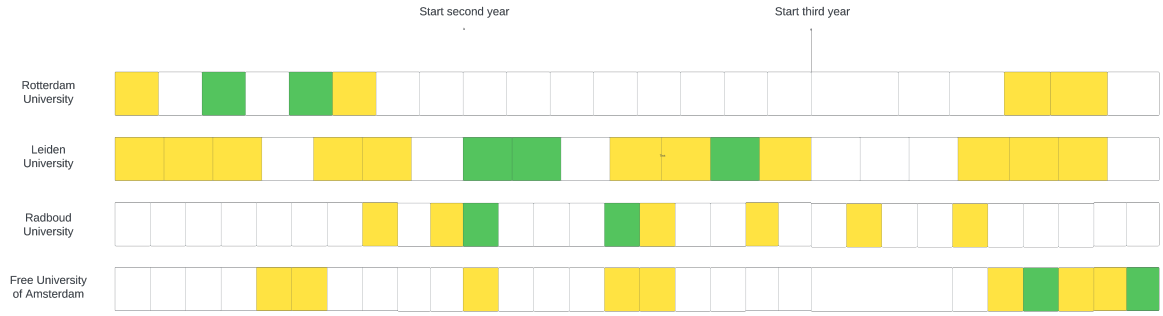

Figure 4 Concise timeline of anticoagulation education present in the bachelor, in which white depicts a course where no anticoagulation is given, yellow depicts a course in which anticoagulation education is given as a secondary focus and green depicts a course in which anticoagulation education is given as a main focus.

The timeline of the master revealed more similarities than differences. Figure 5 shows the timeline of the master. Anticoagulation education was taught extensively in the first year of the master at all four medical schools. What is noteworthy is the timing of the DNPA after the last moment anticoagulation teaching moments differs. Here it seems like RU and the VU conduct the DNPA faster after a subject where anticoagulation education was present as a primary or secondary focus. LEI showed the biggest time difference, as it appeared the DNPA was conducted almost a year after the last course where anticoagulation education was present.

Figure 5 Concise timeline of anticoagulation education present in the Master, in which white depicts a course where no anticoagulation is given, yellow depicts a course in which anticoagulation education is given as a secondary focus and green depicts a course in which anticoagulation education is given as a main focus.

4.3. Practical data and experience

4.3.1. Prescription data

The first part of the practical data pertained to the prescription data obtained from a yet to be published study called BAS-E-RROR. This dataset contained all the prescription prescribed at the Erasmus MC in the month of June, 2021. The number of drugs prescribed was 145.574. The amount of anticoagulation prescriptions was 5.903 or 4,05%. The number of mistakes made across all anticoagulation medication was 0,64%. The distribution of prescriptions across the different drug classes and their relevant error percentage can be found in table 8.

Table 8 Distribution of prescription across the drug classes and the number of mistakes made.

Drug Class	*Prescriptions*	*Mistakes*
TAI	1306 (22,12%)	4 (0,31%)
VKA	436 (7,39%)	1 (0,23%)
LMWH	3569 (60,46)	25 (0,70%)
DOAC	507 (8,59%)	7 (1,38%)
Enzyme	28 (0,47%)	1 (2,63%)
Other	57 (0,97%)	0 (0%)

Furthermore, the dataset containing all the prescriptions (and errors) also noted the reason for the mistake. These mistakes have been noted into several categories. The types of mistakes were checked and these mistakes are shown in table 9.

Table 9 Types of mistakes made

Drug Class	*Double medication*	*Wrong dosage form*	*Interaction*	*Contra-indication*	*Incorrect Dosage*
TAI	1		1		2
VKA	1				
LMWH	14	1		2	8
DOAC	7				
Enzyme	1				
Total	24	1	1	2	10

Table 9 shows that the main part of the caught errors by the hospital pharmacy consisted of double medication and dosage errors. Other errors were present, but in much lesser amounts. In reality these prescription errors were caught by the hospital pharmacist and luckily did not reach the patients. The main form of prescription errors made were double medication errors; prescribing an anticoagulation drug, when anticoagulation drugs are already part of the medication regimen of the patient. Other mistakes were made with the incorrect dosage (form), interaction and contra-indications.

Another interesting part of the BAS-E-RROR study was that the researchers performed a risk assessment of potential consequences if the prescription errors had reached the patients. One double medication error with the VKA prescription had an unknown risk assessment, as it was not clear with which medication the double medication error was coupled. The other results are shown in table 10.

Table 10 Risk assessment by the researchers form the BAS-E-RROR study, if the prescription error did reach the patient.

Drug class	*NCCMERP Index →*	*C*	*D*	*E*	*H*
TAI		0	2	2	0
LMWH		5	0	18	2
DOAC		0	0	7	0
Enzyme		0	0	1	0
Total		5	2	28	2

4.3.2. Interviews about practical experience

In the final part of the results, seven below specialist level doctors were interviewed. three of the doctors were more experienced doctors and graduated from three different medical schools. They have gained multiple years of experience as doctors not in training in different specialties, as researchers and in the first years of their residency training. All three gained their earlier experience in other areas at different hospitals and are currently working at the same medical centre. The other four were considered junior doctors as they had graduated two or three years ago. The four junior doctors have completed their medical school at three different medical schools and gained their current experience as junior doctors at four different hospitals. The four junior doctors, like the other doctors, have held different positions at these hospitals.

As the DNPA was first introduced in 2014 at the RU, none of the three more experienced doctors have taken the DNPA during medical school. Additionally, questions about their opinion about anticoagulation education during their medical study did not hold high value for these results, as their curriculum of ten years ago has long been innovated. However, as they have gained more experience, their answers could provide more insight into practical experience with anticoagulation medication. Fortunately, the four junior doctors have graduated quite recently and three of the four junior doctors have taken the DNPA

The results of these interviews focused on two main themes:

1. Experience with anticoagulation medication.
2. Anticoagulation education and DNPA during medical school.

4.3.2.1. Experience with anticoagulation medication.

Analysing the interview answers in this main theme garnered several categories. Six of the seven doctors have had extensive experience with anticoagulation medications and depending on the department they worked at, could encounter it daily. The other doctor had more experience working at children departments. Therefore, her experience with anticoagulation medication was not as abundant as the other six doctors. When asked about the difficulty level of prescribing anticoagulation medication, all participants replied that it is not that hard if you just follow the hospital protocols.

> *"A lot of health care is protocolled, there are guidelines, hospital protocols, so often it just comes down to following the hospital protocols." (Doctor with ten-year experience)*

Some even mentioned that they would not dare to go against the protocol or supervising doctor with their lesser amount of experience.

Some of them did face some challenges, mostly with VKAs, with the administrative aspect and how you dose this drug class. One even seemed frustrated with the fact that she still did not understand how to dose VKAs. On the other hand, many mentioned that drugs with steady dosage regiments were quite easy to prescribe, although finding the correct dosage can be a puzzle. Although multiple interviewees mentioned that following the protocol is easy, some mentioned that they did not know the mechanism of action by heart. As they did not review that part of knowledge anymore, their basic knowledge on the mechanism of action of some drugs had faded. Furthermore, when asked about other types of challenges they face, few mentioned a moral aspect. In certain situations, an anticoagulation is always administered as a prophylactic treatment, according to hospital protocols. However, not everybody was certain that the prophylactic treatment should be indicated for everyone in the same situation, as administering an anticoagulation *"carries a significant risk."* For the junior doctors this risk assessment of *"weighing the risk of a bleed versus the risk of a thrombosis somewhere,"* is still quite difficult to make. Therefore, the junior doctors follow the protocol or the

supervising doctor, even though they doubt whether the protocol or treatment plan is suited for their patient.

In addition, when asked about the different ways in which the doctors have experienced anticoagulation, several mentioned the distinction between prescribing anticoagulation and encountering complications that could be caused by the use of anticoagulation. One of the junior doctors is currently working on a surgical ward and mentioned that one of the main ways he encounters anticoagulation more than the others, is the discontinuance of anticoagulation medication and whether bridging is needed when a patient needs surgery. After analysing the answers in this category, it became clear that many knew that the different ways doctors encounter anticoagulation also depends on the department they are working at. One of the more experienced doctors described it best.

> *"The ways in which you encounter [anticoagulation medication] and their different indications differs per area, but also the complications, for example, because at the gastroenterology, a DOAC or VKA is never actually prescribed, but you do encounter the complications [of these drugs]." (Doctor with ten-year experience)*

The final category in this theme referenced the mistakes that the doctors have encountered. One mentioned a mistake made by a colleague which had dangerous consequences for a patient. Furthermore, an investigation was started because of this mistake. This experience left a big impact on this doctor and he stated that the most important lesson that he took from this experience is that you should

> *"Restart anticoagulation when a patient goes home, restart anticoagulation when a patient goes home, restart anticoagulation when a patient goes home. You do not want to mess that up." (Doctor on a surgical ward)*

Other mistakes pertaining anticoagulation were dosage mistakes with VKAs, overlooked interactions between VKAs and NSAIDs and omeprazole and clopidogrel and mistakes with indication (either with not prescribing anticoagulation when an indication is present or continuing anticoagulation when the indication disappears). Usually, these mistakes had no consequences for the patient, but a handful of these mistakes with the combination between a NSAID and a VKA resulted in stomach bleeds and a patient that did not receive prophylactic treatment developed a pulmonary embolism.

4.3.2.2. Anticoagulation education and the DNPA

The second main theme was about anticoagulation education and the DNPA. These answers held less information, as most could not remember in detail how they had experienced anticoagulation during medical school. However, the answers did provide interesting and useful information. The answers by the more experienced doctors referenced to the curriculum of the past, which have been innovated by now. Therefore, the focus lies more on the answers given by the junior doctors, as their experience with anticoagulation education during medical school was more recent and more relevant to the current curriculum. All junior doctors had similar answers. Everybody believes that there must have been some type of anticoagulation education during medical school, but none of them remembered the lectures or quality clearly, except for the general build-up of courses. However, after careful consideration few did mention that they must have been given the basic knowledge about anticoagulation medication and several subjects in which anticoagulation is present, but they did not remember in full detail what it was about. When asked about their opinion on the fact that they do not remember the lectures and quality of anticoagulation education, opinions differed. Two mentioned their surprise at the (lack of) anticoagulation education, as they encounter these drugs every day. On the other hand, one was fine with it, as she admitted that she expects that she would not have known the basic mechanism of action better, because

"That is not where my interests lie." (Junior doctor)

When asked about the DNPA, three of the four junior doctors revealed that they have taken the DNPA. Unfortunately, the three doctors could not remember much details about the test itself, as they had taken the test at least two or three years ago. However, all three mentioned that it definitely added value to their medical education. One proclaimed genuine enthusiasm about the test:

"I do think the test really has added value, I remember that I was very excited about it, when I made it. I really enjoyed learning it and finally knowing something about it." (Junior doctor)

What is noteworthy, is that all three of them mentioned that the test was fairly easy, because the test was literally about the subject matter offered in the reader. One was surprised by how easy it was, considering all the stress that his fellow students had in anticipation of the DNPA. All three did mention the clarity of the reader as reason for how easy the DNPA was. All three only had positive things to say about this reader, one even jokingly mentioned

"Oh, so this is what I have been doing all the time during my internships." (Junior doctor)

Two of the doctors also mentioned that it would be useful to currently refresh their basic knowledge on the basics of haematology and anticoagulation medication. Therefore, the link to the reader was again sent to these two doctors as a basic reference book. Moreover, when mentioning the positive opinion about the DNPA reader to the fourth junior doctor, the one that did not make the DNPA, she also wanted to have the reader and even mentioned sending the reader to her friends. Another theme that came up was the timing of the reader. All three suggested that the reader could be mentioned earlier and more often during medical school. Consequentially, one could learn more about medication during their internships if they knew that the reader was available and studied. Two even mentioned that the test could be conducted before all the internships started.

"I experienced [the test] as very nice and actually everybody said that it was very nice and that they would have preferred to see the test two years earlier." (Junior doctor)

However, one of them later admitted that it would be a risk, as it could be too much information, for example, at the start of the master. Another doctor went a step further and suggested that it could be useful to conduct a similar test in each year of the master.

5. Discussion

As mentioned in the introduction and seen in the prescription data, medication errors with anticoagulation medication are still common. Anticoagulation errors that reach patients can potentially put a high burden on patients and influence their quality of life. Therefore, reducing prescribing errors with anticoagulation medication has a high priority, as anticoagulation medication is still prescribed daily. Improving anticoagulation education at medical schools could be one of the solutions in reducing anticoagulation errors. To identify opportunities to improve anticoagulation in medical school a triangulation of DNPA results, curriculum mapping and practical data and experiences has been performed. Results showed that medical schools score higher in different drug classes and associated subjects than others. Second, the amount of anticoagulation in medical schools could be focused in a different period of time during their six-year education. Furthermore, practical data and experiences have shown different experiences and challenges pertaining to

anticoagulation medication. Results also showed similar junior doctor opinions on anticoagulation education and DNPA

5.1. Interpretation

Quantitative analysis of the test data showed that different medical schools performed differently in the different drug classes and associated drug subjects. LEI performed worse than the other three universities in LMWHs and DOACs, but performed higher than EUR with questions about combination of drug classes. EUR performed worse than the other three universities in the questions that combine knowledge about multiple drug classes, but excelled at LMWH and DOAC questions. RU and VU had the highest overall scores pertaining to anticoagulation and had similar results. However, RU performed slightly better than VU at TAIs and VU performed slightly better than RU with LMWH questions. At these two medical schools the scores of the other three drug classes did not fall below 82,4%. Reasons for the differences in performance in the drug classes can be found in different subjects. Recurring subjects that had the highest practical significant differences were antidote and drug properties. Analysis of the competence level revealed that student score better in questions with lower competence level. However, two drug classes did not follow this trend. These were TAIs and LMWHs. In these drug classes students scored better in 'understand' level question than 'remember' questions. It is possible that students understand these drug classes better than they remember the details.

Curriculum mapping of the four medical schools revealed that LEI has the longest period between a course, in which anticoagulation was mentioned as the main or secondary focus, and the DNPA. This 'drought' of anticoagulation education was the shortest for RU and VU, the two medical schools with the highest overall schools. Moreover, the DNPA was conducted at RU during a course, in which anticoagulation medication was mentioned as a secondary focus. Student questionnaires in preliminary studies revealed that faded knowledge was one of the main reasons why students found the anticoagulation part of the DNPA so difficult to study for. Having any kind of anticoagulation education close to the DNPA can be a trigger for students to remember more about the subject matter. Therefore, the timing of anticoagulation education (as either main or secondary focus) and the DNPA can be a contributory factor for the disparity in anticoagulation scores. This could be a reason for the high anticoagulation scores of RU and VU. Furthermore, students of LEI still have not caught up to the scores of the other medical schools. (22)

In the analysis of practical results, it is worth to mention that the interviewed doctors have acquired their experience from several medical facilities and went to medical school in different medical schools. Therefore, answers are not focused in one location, but can be applied to general experiences. Qualitative analysis showed that the below specialist level doctors did not find it complicated to prescribe anticoagulation drugs, because they are following hospital protocols. A possible explanation could be that the doctors are less forced to think for themselves and do not have to decide if they should prescribe an anticoagulant drug or choose which anticoagulant they should prescribe if indicated. Especially for the junior doctors, courage to deviate from protocol or treatment plan of a supervising doctor is absent, as they are far less experienced. Furthermore, difficulties in finding the right dosage with VKAs seemed to be a recurring theme. However, this dosage errors with VKAs were not found in the prescription data. Interviews revealed that overlooked interactions, for example between a VKA and NSAID, were reasons for mistakes. Student questionnaires in preliminary studies revealed interactions as one of the more difficult subjects, students had to study for. Therefore, this might be an interesting subject to include more in the curriculum of medical schools. Other mentioned mistakes involved unnecessary prescribing and failing to prescribe when an indication is present. Preliminary research also indicated that several medical schools had higher error percentages in indication questions.

Analysis of the experiences with anticoagulation education during medical school and the DNPA revealed that all participants mentioned a lack of focus on pharmacotherapy related subject matter. Some were even surprised at the lack of focus on anticoagulation medication, as they encounter them daily. However, not everyone shared the same view on the necessity of more pharmacotherapy related education, as an abundance of medical knowledge in other areas is currently required to graduate medical schools. Other statements were made about the DNPA and that it definitely has added value for the medical education and profession. Unfortunately, too much time has passed for the doctors to remember details about the DNPA other than concrete experiences with the low difficulty of the test, if one studied the reader sufficiently. The reader is also the most positive aspect that they do recall, as they were very pleased with how easy it was to understand and the excellent clarity. Due to the positive opinion about the reader, all were surprised it was not available earlier on during medical school. Combined with enjoyable experience associated with making the test, two of the doctors even made a bold claim by suggesting to conduct the test much earlier in the master.

Unfortunately, the amount of anticoagulation prescriptions in the dataset was not sufficient enough. Naturally, every (anticoagulation) prescription error is one error too much. Unfortunately for this research, the number of prescribing mistakes were not enough to form concrete statements about the anticoagulation prescribing errors made at the medical centre. However, it was seen that prescription errors with dosage, contra-indication and interactions were possible errors.

5.2. Implication

Improving anticoagulation education on medical schools is a big challenge. The suggestion to increase the amount of teaching moments in the curriculum is an obvious possibility, but it comes with certain difficulty. The six-year medical study is already filled with an abundance of lectures, assignments and self-study assignments. If the quantity of anticoagulation teaching moments is increased, it could be difficult to determine what subject matter will receive less focus. And even if the quantity of anticoagulation medication is increased, it does not guarantee students will see the necessity of the matter and remember information pertaining to anticoagulation medication better. Therefore, it is recommended to have a bigger focus on the improvement of the quality instead of the quantity of anticoagulation education.

One potential way to improve the quality of anticoagulation education is to learn from other medical schools. Analysis of the test results in the four medical school revealed which medical schools performed better in which drug classes and subjects. Furthermore, an analysis of the competence level could provide insight into which drug classes and subjects a school can learn most from. When students have lower scores on remember questions, it does not necessarily mean that the quality of anticoagulation education needs improving. Answering ‘remember’ questions incorrectly could also mean that a student did not have enough repetition or did not put enough effort into learning the subject matter by heart. An incorrect answer on the level of understanding or application however could tell another story. It could mean that a student remembered the subject matter, but they did not have or never had a sufficient understanding of the knowledge or how to apply it. Moreover, a better understanding of subject matter (almost certainly) guarantees a bigger possibility of remembering and applying it correctly. Therefore, combining the results from the drug class and subject analysis with the results from the competence level analysis could potentially provide more insight into which universities can profit most by learning from other medical schools. An example for this is the TAIs. EUR and VU have similar scores on the level of remember, but the disparity in scores of the level understand is significant. Furthermore, test scores in the subjects, mechanism of action and dosage, showed the biggest disparities. Between these two medical schools. Therefore, studying the differences in the curriculum could contribute to identifying opportunities to improve anticoagulation education in those subjects at the EUR.

An overview of medical schools that score lower on certain drug classes and relevant subjects is shown in table 11. The final column suggests the medical school they could learn the most from based on both subject and competence level results.

Table 11 The lower scoring medical schools and schools that could provide the most insight into improving education on the drug classes and subjects.

Drug Class	*Subject*	*Lower scoring medical school(s)*	*Medical school with the most potential to learn something from*
TAI	Overall	EUR, LEI	RU
	Mechanism of action	EUR	RU
	Dosage	EUR, LEI	RU
	Drug discontinuance	VU	RU
	Platelet life	EUR	VU
VKA	Overall	EUR, LEI	VU
	Interaction	EUR, LEI	RU
	Antidote	EUR	VU
	Bridging	EUR	VU
LMWH	Overall	LEI	EUR
	Antidote	LEI	RU
	Drug properties	LEI	VU
DOAC	Overall	LEI	RU
	Antidote	LEI	VU
	Drug properties	All four scored below 67,7%	All four need to improve on this subject matter
Combination of drug classes	Overall	EUR	VU
	Indication	EUR	VU
	ADME	EUR	VU

However, these results need to be viewed with caution, as there are disparities in the number of questions in some of the different subjects from each of the medical schools. For example, LEI only had seventeen questions pertaining to the antidote of DOACs, while the other three medical schools had at least 98. This subject also showed the biggest practical significance, as LEI scored significantly lower than each of the other three medical schools. It is plausible the scores of LEI would have increased if more test data was included. Furthermore, a greater amount of DNPA data could also provide more insight.

Unfortunately, there were many differences in the extensiveness and methods used in the curriculum mapping done in the four preliminary studies. Therefore, only a coarse analysis could be performed. This revealed that the time period between the final course, in which anticoagulation education is taught as a primary or secondary focus, could contribute to the anticoagulation scores on the DNPA. Therefore, it is recommended to reducing the time period between the final teaching moment, in which anticoagulation medication is taught as a primary or secondary focus, before the DNPA. Reducing this time period means that knowledge on subject matter will have a shorter time to fade. One solution is to offer short anticoagulation refresher lectures or small assignments for the students to refresh their knowledge in long time periods without any anticoagulation medication related courses. This is especially the case for LEI, where a yearlong break exists between the last course in which anticoagulation medication is taught and the DNPA. The suggestion to move the DNPA forward, should be viewed critically, however. One of the possible explanations for why the interviewed doctors did not find the DNPA difficult, could be that the test was conducted after the internships, in which it is possible that they gained practical experience with anticoagulation medication before the DNPA. It is an absolute possibility that the acquired experience with the medication is a contributing factor to the low difficulty of the test.

The combination of answers from the interviews and curriculum mapping revealed that it could be necessary to revaluate the timing of the introduction of study material for the DNPA. It could be imperative to announce the availability of the reader much earlier and more often in the master. Because of the clarity and conciseness of the reader, it should not take much time for the students to review the chapters regarding drugs relevant to the learning goals of their current course. Moreover, more practice and experience, while reviewing basic knowledge on relevant drugs, can help medical students to improve their understanding of how a drug works at a certain level. An improvement of understanding the subject matter could lead to higher scores at apply questions and less effort needed to remember the information. Therefore, this change could possibly provide an increase in scores at all three competence levels.

Furthermore, practical data suggests that prescription errors with dosage, contra-indication and interactions are possible. The DNPA has a number of questions about interactions. However, analysis of questions on the DNPA showed that not all subjects are present in every drug class. Dosage questions, for example, are only present for TAIs. Some doctors mentioned difficulties with finding the right dosage for VKAs. A suggestion could be made to include VKA dosage subject matter into the reader to better prepare medical students for their professional career. Furthermore, none of the questions asked information about contra-indications, while the information is present for some drugs in the reader. Another suggestion could be to introduce questions about this subject into the DNPA. However, these results should be taken with a grain of salt, as there were not enough prescription errors to make concrete statements about what types of errors are more common in daily practice.

5.3. Strengths and limitations

Identifying opportunities to improve anticoagulation education at medical schools proved to be a difficult challenge. However, collecting data from DNPA results, curriculum mapping and practical data and experience provided a rich database of information to meet the challenge. Through the use of triangulation, three perspectives were used in the identification of opportunities to improve anticoagulation education. DNPA data was collected from four universities, which provided a big dataset of test scores to compare and analyse. Furthermore, it is almost certain no mistakes were made comparing the test data from the four medical schools, as every question was thoroughly reviewed and matched to each other. Another strength was the addition of practical data and experience. Practical experience revealed potential challenges junior doctors still struggle with at the beginning of their professional career. As hindsight is 20/20, the interviews also provided insight to their experience with anticoagulation medication and the DNPA. The DNPA reader could be undervalued, if the enormous appreciation for the reader was not discovered. Furthermore, the interviewed doctors acquired practical experience in different medical centres and studied at different medical schools. Therefore, information acquired through the interviews offered a broad perspective on experience with anticoagulation medication in their profession and medical education.

However, there were limitations as well. Test data from the four universities was collected in a different time period relative to the introduction of the DNPA The EUR and LEI test data was collected closer to the implementation of the DNPA As mentioned earlier, tests are made comparably worse in the start-up period after implementation. As no literature was found explaining how many months or test moments this start-up period generally takes, the number of test moments that were assigned to the start-up period was based on the number of half-lives needed for a drug to reach steady state. However, test moments are definitely not the same as drugs and the provided test data had some discrepancies. Test data from the VU were not from successive test moments. It had several gaps between the test moments as the conducted tests at these gaps had different test versions than the test versions used at the other medical schools. Test moments from different

medical schools also contained a different number of participants. For example, some tests at EUR had more than 100 participants, whereas test moments at the LEI primarily had around 30-35 participants. This caused the ten test versions to be made by a different number of participants at the medical schools, resulting in discrepancies the number of obtained answers in some subjects and competence levels. Moreover, test moments at the EUR were separated by a bigger time period than LEI. This complicated finding the right number of test moments to include in the start-up period. Even though tests made by humans are not drugs, it is very plausible that different numbers of people (dosage) and different time periods between test moments (dosage interval) contributes to the exact test moment steady state was reached. Therefore, it is very plausible that more or a different amount of test moments were required for the two medical schools to reach steady state test scores and the test scores at EUR and LEI are underestimated. However, when more tests are excluded, less data is available to be analysed. However, the test data still provided useful information. For example, if the DOACs and LMWHs at EUR are an underestimate, how big is the improvement when precise scores are analysed? Ideally, future research is done with a bigger database with comparable “dosages” and “dosage intervals” of test data in steady state. This will ensure a better reflection of the actual test scores at the medical schools.

Another limitation is the collected data pertaining curriculum scans. The biggest discrepancy is the method in which the four studies have mapped the curriculum. The data acquisition and depth of curriculum mapping and analysis varied the most between the four datasets. The combined timeline could only depict whether courses had anticoagulation education as a primary or secondary focus. Consequentially, it made it impossible to compare the medical schools on a deeper level. Nothing could be said about the relative amount of time spent or depth reached in the different drug classes, subjects and competence levels. This could be a cause for the number of courses at LEI that have mentioned anticoagulation education as a secondary focus. It is not clear to which extent it is taught in these courses. It could be possible that it is taught as tertiary focus, but without details this will stay unknown. However, the analysis of the curriculum mapping did provide useful information. It suggested that one of the potential reasons medical schools score better or lower in anticoagulation medication can be contributed to the timing of subject matter and DNPA. Future research should aim to perform curriculum mapping more thoroughly, with a similar method and categorising the data in the same categories as the DNPA drug classes and details. Consequently, the curriculum mapping could be analysed in more detail and linked to the DNPA results.

Next, the dataset provided by the BAS-E-RROR study also presented some limitations. To study all clinical prescriptions, they recorded the clinical prescriptions of one month at the Erasmus MC. Focusing on the amount of anticoagulation prescriptions and medication errors made in this area, it was concluded the number of prescription and errors was insufficient to find definitive links between the practical data and DNPA data. Second, it proved to be a challenge to categorize the medication errors in the exact same subjects used for the categorization of the DNPA questions. Finally, the dataset contained clinical prescriptions of the Erasmus MC, without prescriptions made by general practitioners. In addition, the number of conducted interviews was small and the interviews were with doctors who had no experience in the general practice. Consequentially, there is an overrepresentation of specialist prescription and no representation of general practitioner experience compared to the real world. In the future, a bigger dataset including prescriptions made by general practitioners and interviews would offer a better reflection of the real world. However, the practical data did provide useful and insightful information that should encourage future researchers to acquire more and variable anticoagulation prescription data and to conduct more interviews with junior doctors.

6. Conclusion

In conclusion, identification of opportunities to improve anticoagulation education at medical schools yielded four main recommendations. First, cooperation between medical schools is important. Studying the way medical schools teach their students in the higher scoring drug classes and subjects could help identify factors that explain why these students perform better. Lower scoring medical schools could use these factors to improve anticoagulation medication in those drug classes and subjects in their own curriculum. Second, the time period between anticoagulation medication related subject matter and the DNPA should be reduced by offering concise refresher lectures or assignments. Third, it is imperative that knowledge about the existence of the reader is announced early and often. This provides students with more possibilities to gain more practice and experience with understanding and applying the subject matter in the reader. Finally, the DNPA subject matter and questions could be revised and questions pertaining important subjects in practice could be added to the question pool, as some questions are on 2 or more different test versions. Implementation of all four recommendations could potentially provide better anticoagulation education for medical students to become better anticoagulation prescribing junior doctors in the future.

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8. Appendices

8.1. Appendix A List of anticoagulation drugs for search in prescription data

Pharmaco active substance	Name	Klasse
Acetylsalicylzuur	Acetylsalicylzuur	TAI
Acetylsalicylzuur	Aspirine protect	TAI
Carbasalaatcalcium	ASCAL cardio neuro	TAI
Carbasalaatcalcium	Carbasalaatcalcium	TAI
Clopidogrel	Clopidogrel	TAI
Clopidogrel	Plavix	TAI
Dipyridamol	Dipyridamol	TAI
Dipyridamol	Persantin	TAI
Epoprostenol	Epoprostenol	TAI
Epoprostenol	Flolan	TAI
Iloprost	Iloprost	TAI
Iloprost	Ventavis	TAI
Prasugrel	Efient	TAI
Prasugrel	Prasugrel	TAI
Selexipag	Selexipag	TAI
Selexipag	Uptravi	TAI
Ticagrelor	Brilique	TAI
Ticagrelor	Ticagrelor	TAI
Treprostinil	Remodulin	TAI
Treprostinil	Treprostinil	TAI
Acenocoumarol	Acenocoumarol	VKA
Fenprocoumon	Fenprocoumon	VKA
Fenprocoumon	Marcoumar	VKA
Dalteparine	Dalteparine	(LMW)H
Dalteparine	Fragmin	(LMW)H
Enoxaparine	Enoxaparine	(LMW)H
Enoxaparine	Inhixa	(LMW)H
Fondaparinux	Arixtra	(LMW)H
Fondaparinux	Fondaparinux	(LMW)H
Heparine	Heparine	(LMW)H
Nadroparine	Fraxiparine	(LMW)H
Nadroparine	Nadroparine	(LMW)H
Tinzaparine	Innohep	(LMW)H
Tinzaparine	Tinzaparine	(LMW)H
Apixaban	Apixaban	DOAC
Apixaban	Eliquis	DOAC
Dabigatranetexilaat	Dabigatran etexilaat	DOAC
Dabigatranetexilaat	Pradaxa	DOAC

Edoxaban	Edoxaban	DOAC
Edoxaban	Lixiana	DOAC
Rivaroxaban	Rivaroxaban	DOAC
Rivaroxaban	Xarelto	DOAC
Alteplase	Actilyse	Enzymes
Alteplase	Alteplase	Enzymes
Urokinase	Medacinase	Enzymes
Urokinase	Urokinase	Enzymes

8.2. Appendix B Pharmacotherapy exam analysis

8.2.1. Appendix B.1. Test scores and chi square tests drug classes

Table 12 Drug class test scores and chi-square tests.

Drug Class	*EUR*	*LEI*	*RU*	*VU*	*Chi-Square significance*	*Cramer's V value*
TAI	82,9 (1607)	83,5 (1190)	90,4 (1853)	86,7 (1785)	<,001	,089
VKA	81 (1829)	80,2 (1210)	87,9 (1790)	88,2 (1752)	<,001	,102
LMWH	90,1 (583)	75,4 (418)	86,0 (658)	89,0 (657)	<,001	,150
DOAC	88,6 (878)	66,7 (291)	84,7 (544)	82,4 (507)	<,001	,186
Combi	72,7 (1295)	87,7 (536)	87,7 (960)	89,2 (888)	<,001	,197

Table 13 Drug class "steady state" test scores and chi-square tests.

Drug Class	*EUR*	*LEI*	*RU*	*VU*	*Chi-Square significance*	*Cramer's V value*
TAI	84,8 (1160)	84,7 (795)	90,4 (1853)	86,7 (1785)	<,001	,071
VKA	82,4 (1470)	83,3 (730)	87,9 (1790)	88,2 (1752)	<,001	,076
LMWH	93,3 (420)	74,0 (231)	86,0 (658)	89,0 (657)	<,001	,164
DOAC	89,6 (779)	63,1 (157)	84,7 (544)	82,4 (507)	<,001	,190
Combi	72,1 (1121)	88,1 (337)	87,7 (960)	89,2 (888)	<,001	,205

8.2.2. Appendix B.2. Test scores and chi square tests thrombocyte aggregation inhibitors.

Table 14 TAI subject test scores and chi square tests.

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	83,1 (687)	84,5 (278)	93,5 (417)	92,6 (474)	<,001	,148
Indication	91,2 (34)	81,1 (132)	86,0 (207)	87,9 (173)	,281	
Mechanism of action	82,2 (267)	91,9 (136)	97,2 (246)	96,1 (256)	<,001	,230
Dosage	73,6 (53)	79,7 (59)	96,6 (87)	92,0 (88)	<,001	,269
Drug Properties	79,3 (87)	87,4 (191)	94,9 (294)	94,3 (261)	<,001	,181
Discontinuation of drug	80,4 (92)	69,5 (197)	77,1 (345)	51,7 (292)	<,001	,244
Platelet life	85,6 (277)	84,4 (64)	96,9 (130)	98,1 (103)	<,001	,201
Side effects	84,6 (52)	91,7 (133)	89,8 (127)	94,9 (138)	,131	
Remember	83,3 (867)	83,5 (853)	89,1 (1349)	84,0 (1223)	<,001	,072
Understand	82,4 (740)	83,7 (337)	94,0 (504)	92,5 (562)	<,001	,162

Table 15 TAI subject "steady state" test scores and chi square tests

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	85,8 (522)	91,4 (140)	93,5 (417)	92,6 (474)	<,001	,114
Indication	100 (14)	78,7 (94)	86,0 (207)	87,9 (173)	,081	
Mechanism of action	83 (253)	97,6 (83)	97,2 (246)	96,1 (256)	<,001	,242
Dosage	67,6 (34)	79,7 (59)	96,6 (87)	92,0 (88)	<,001	,300
Drug Properties	89,6 (48)	86,9 (153)	94,9 (294)	94,3 (261)	,010	,122
Discontinuation of drug	66,7 (6)	70,7 (133)	77,1 (345)	51,7 (292)	<,001	,246
Platelet life	85,6 (277)	81,3 (32)	96,9 (130)	98,1 (103)	<,001	,210
Side effects	83,3 (6)	89,1 (101)	89,8 (127)	94,9 (138)	,285	
Remember	84,9 (604)	83,6 (596)	89,1 (1349)	84,0 (1223)	<,001	,070
Understand	84,7 (556)	87,9 (199)	94,0 (504)	92,5 (562)	<,001	,132

For the next tables only Cramer's V values are shown for statistically significant differences. No value means that the chi square test was not significant. In the multiple 3 medical school chi-square tests, the top shows the medical school that was absent in this analysis. W/O EUR, means the chi square test was done with the medical schools of LEI, RU and VU.

Table 16 multiple 3 medical school Cramer's V values

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,082	,091	,048	,103
Interaction	,127	,156	,126	,135
Indication				
Mechanism of action		,246	,204	,220
Dosage	,228	,292	,213	,285
Drug Properties	,121	,199	,176	,189
Discontinuation of drug	,237	,274	,232	
Platelet life	,239	,207	,167	,163
Side effects				
Remember	,075	,076		,082
Understand	,144	,170	,134	,153

Table 17 multiple 3 medical school Cramer's V values in steady state

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,070	,070		,086
Interaction		,119	,106	,119
Indication			,153	,130
Mechanism of action		,238	,230	,248
Dosage	,228	,334	,252	,325
Drug Properties	,124		,121	,135
Discontinuation of drug	,247	,265	,178	
Platelet life	,255	,207	,178	,173
Side effects				
Remember	,075	,070		,073
Understand	,078	,139	,113	,137

For the next tables only phi values are shown for statistically significant differences. No value means that the chi square test was not significant.

Table 18 One versus one Phi values

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall		,112	,053	,103	,044	,059
Interaction		,150	,139	,146	,128	
Indication						
Mechanism of action	,125	,234	,215	,118		
Dosage		,341	,251	,273	,181	
Drug Properties		,233	,221	,134	,120	
Discontinuation of drug			,249		,178	,266
Platelet life		,171	,177	,228	,258	
Side effects			,171			
Remember		,084		,081		,075
Understand		,170	,148	,169	,138	

Table 19 One versus one Phi values in steady state

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall		,085		,084		,059
Interaction		,124	,109			
Indication					,121	
Mechanism of action	,185	,236	,214			
Dosage		,406	,308	,273	,181	
Drug Properties				,141	,127	
Discontinuation of drug					,178	,266
Platelet life		,171	,177	,259	,303	
Side effects						
Remember		,059		,077		,075
Understand		,150	,123	,103	,072	

8.2.3. Appendix B.3. Test scores and chi square tests Vitamin K antagonists.

Table 20 VKA subject test scores and chi square tests.

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	78,3 (492)	75,9 (581)	88.3 (755)	82,3 (716)	<,001	,125
ADME	75,8 (95)	64,9 (77)	76.2 (101)	83,2 (113)	,039	,147
Antidote	80,8 (396)	88,2 (221)	93.9 (345)	96,6 (348)	<,001	,212
Drug Properties	95,6 (616)	97,4 (191)	98.7 (306)	98,8 (333)	,009	,089
Bridging	50,4 (230)	70,7 (140)	72.1 (283)	81,8 (242)	<,001	,252
Remember	82,6 (955)	83,7 (540)	85.8 (823)	90,6 (810)	<,001	,090
Understand	79.3 (874)	77,5 (670)	89.8 (967)	86,2 (942)	<,001	,134

Table 21 VKA subject "steady state" test scores and chi square tests

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	78,9 (342)	79,7 (364)	88.3 (755)	82,3 (716)	<,001	,102
ADME	75,9 (83)	70,8 (24)	76.2 (101)	83,2 (113)	,408	
Antidote	77.9 (331)	88,1 (134)	93.9 (345)	96,6 (348)	<,001	,251
Drug Properties	95,8 (544)	96,6 (117)	98.7 (306)	98,8 (333)	,017	,089
Bridging	58,8 (170)	76,9 (91)	72.1 (283)	81,8 (242)	<,001	,187
Remember	85,8 (811)	85,9 (326)	85.8 (823)	90,6 (810)	<,008	,065
Understand	78,3 (659)	81,2 (404)	89.8 (967)	86,2 (942)	<,001	,124

For the next tables only Cramer's V values are shown for statistically significant differences. No value means that the chi square test was not significant. In the multiple 3 medical school chi-square tests, the top shows the medical school that was absent in this analysis. W/O EUR, means the chi square test was done with LEI, RU and VU.

Table 22 multiple 3 medical school Cramer's V values

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,099	,096	,098	,094
Interaction	,132	,110	,067	,146
ADME	,169		,171	
Antidote	,131	,234	,214	,173
Bridging	,114	,273	,296	,211
Remember	,075	,076		,082
Understand	,137	,121	,098	,147

Table 23 multiple 3 medical school Cramer's V values in steady state

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,054	,075	,078	,073
Interaction	,097	,102		,123
ADME				
Antidote	,123	,268	,258	,214
Bridging	,106	,195	,235	,149
Remember	,075	,070		,073
Understand	,090	,128	,093	,145

For the next tables only phi values are shown for statistically significant differences. No value means that the chi square test was not significant.

Table 24 One versus one Phi values

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall		,095	,100	,105	,110	
Interaction		,136		,164	,078	,086
ADME					,209	
Antidote	,096	,194	,243	,100	,162	
Bridging	,199	,222	,332		,129	,115
Remember		,084		,081		,075
Understand		,146	,092	,168	,113	,055

Table 25 One versus one Phi values in steady state

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall		,077	,082	,062	,067	
Interaction		,123		,115		,086
ADME						
Antidote	,116	,231	,281	,098	,163	
Bridging	,181	,137	,253			,115
Remember		,059		,077		,075
Understand		,158	,103	,117	,064	,055

8.2.4. Appendix B.4. Test scores and chi square tests low molecular weight heparins.

Table 26 subject test scores and chi square tests.

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
ADME	95,4 (372)	100 (60)	100 (93)	96,6 (117)	,008	,106
Mechanism of action	88,4 (86)	78,6 (145)	80,4 (204)	86,9 (213)	,072	
Antidote	75 (72)	67,2 (137)	88.8 (206)	87,5 (192)	<,001	,234
Drug Properties	75,5 (53)	64,5 (76)	81.3 (155)	88,1 (135)	<,001	,205
Remember	80,6 (211)	71,2 (358)	83.7 (565)	87,4 (540)	<,001	,154
Understand	95,4 (372)	100 (60)	100 (93)	96,6 (117)	,008	,106

Table 27 subject "steady state" test scores and chi square tests

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
ADME	95,3 (360)	100 (24)	100 (93)	96,6 (117)	,021	,099
Mechanism of action	90 (20)	76 (75)	80,4 (204)	86,9 (213)	,091	,112
Antidote	83,3 (6)	67,1 (73)	88.8 (206)	87,5 (192)	<,001	,212
Drug Properties	76,5 (34)	69,5 (59)	81.3 (155)	88,1 (135)	,017	,163
Remember	81,7 (60)	71 (207)	83.7 (565)	87,4 (540)	<,001	,145
Understand	95,3 (360)	100 (24)	100 (93)	96,6 (117)	,021	,099

For the next tables only Cramer's V values are shown for statistically significant differences. No value means that the chi square test was not significant. In the multiple 3 medical school chi-square tests, the top shows the medical school that was absent in this analysis. W/O EUR, means the chi square test was done with LEI, RU, VU.

Table 28 multiple 3 medical school Cramer's V values

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,149		,177	,159
ADME	,140	,088		,117
Mechanism of action				
Antidote	,244	,139	,224	,243
Drug Properties	,218		,252	,166
Remember	,165	,069	,181	,136
Understand	,140	,088		,117

Table 29 multiple 3 medical school Cramer's V values in steady state

Subject or Bloom's taxonomy level	W/O EUR	W/O LEI	W/O RU	W/O VU
Overall	,142	,090	,203	,189
ADME		,091		,110
Mechanism of action				
Antidote	,214		,234	,252
Drug Properties	,167		,212	
Remember	,149		,187	,137
Understand		,091		,110

For the next tables only phi values are shown for statistically significant differences. No value means that the chi square test was not significant.

Table 30 One versus one Phi values

Subject or Bloom's taxonomy level	EUR/LEI	EUR/RU	EUR/VU	LEI/RU	LEI/VU	RU/VU
Overall	,197	,062		,135	,181	
ADME		,097				
Mechanism of action					,109	
Antidote		,171	,152	,266	,246	
Drug Properties			,158	,184	,282	
Remember	,104		,087	,149	,202	
Understand		,097				

Table 31 One versus one Phi values in steady state

Subject or Bloom's taxonomy level	EUR/LEI	EUR/RU	EUR/VU	LEI/RU	LEI/VU	RU/VU
Overall	,270	,113	,072	,140	,185	
ADME		,100				
Mechanism of action					,130	
Antidote				,255	,236	
Drug Properties					,226	
Remember				,142	,195	
Understand		,100				

8.2.5. Appendix B.5. Test scores and chi square tests direct oral anticoagulants.

Table 32 subject test scores and chi square tests.

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
ADME	89,8 (549)	90 (60)	94.7 (151)	94,2 (172)	,125	
Mechanism of action		74,1 (81)	82.6 (138)	70,7 (99)	,082	
Antidote	90,6 (277)	76,5 (17)	92.2 (128)	99 (98)	,005	,158
Drug Properties	65,4 (52)	50,4 (133)	67.7 (127)	64,5 (138)	,02	,148
Remember	90,1 (826)	87 (77)	93.5 (279)	95,9 (270)	,005	,093
Understand	65,4 (52)	59,3 (214)	75.5 (265)	67,1 (237)	,003	,137

Table 33 subject "steady state" test scores and chi square tests

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
ADME	89,3 (496)	91,7 (24)	94.7 (151)	94,2 (172)	,090	
Mechanism of action		75 (32)	82.6 (138)	70,7 (99)	,092	
Antidote	90,6 (277)		92.2 (128)	99 (98)	,024	,122
Drug Properties	66,7 (6)	52,5 (101)	67.7 (127)	64,5 (138)	,112	
Remember	89,8 (773)	91,7 (24)	93.5 (279)	95,9 (270)	,009	,092
Understand	66,7 (6)	57,9 (133)	75.5 (265)	67,1 (237)	,004	,143

For the next tables only Cramer's V values are shown for statistically significant differences. No value means that the chi square test was not significant. In the multiple 3 medical school chi-square tests, the top shows the medical school that was absent in this analysis. W/O EUR, means the chi square test was done with LEI, RU and VU.

Table 34 multiple 3 medical school Cramer's V values

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,176	,075	,211	,213
ADME				
Mechanism of action		Era absent	Era absent	Era absent
Antidote	,239	,122	,181	
Drug Properties	,154			,169
Remember	,114	,088	,095	
Understand	,141			,164

Table 35 multiple 3 medical school Cramer's V values in steady state

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall	,178	,089	,222	,221
ADME		,089		
Mechanism of action		Era absent	Era absent	Era absent
Antidote	LUMC absent	,122	LUMC absent	LUMC absent
Drug Properties	,128			
Remember		,093	,095	
Understand	,144			,179

For the next tables only phi values are shown for statistically significant differences. No value means that the chi square test was not significant.

Table 36 One versus one Phi values

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall	,253	,056	,087	,209	,180	
ADME						
Mechanism of action	ERA absent	ERA absent	ERA absent			,030
Antidote			,142	,171	,392	,019
Drug Properties				,176	,143	
Remember			,091		,155	
Understand				,172		,093

Table 37 One versus one Phi values in steady state

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall	,279	,073	,103	,226	,198	
ADME		,078				
Mechanism of action	ERA absent	ERA absent	ERA absent			,030
Antidote	LUMC absent		,142	LUMC absent	LUMC absent	,019
Drug Properties				,155		
Remember			,096			
Understand				,180		,093

8.2.6. Appendix B.6. Test scores and chi square tests combination of drug classes.

Table 38 subject test scores and chi square tests.

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	100 (14)	94,4 (72)	97,1 (68)	100 (73)	,190	
Indication	76 (1056)	85 (200)	86,2 (494)	86,9 (465)	<,001	,132
ADME	51,3 (197)		82.6 (132)	84 (106)	<,001	,343
Antidote	71,4 (14)	81,8 (132)	83.5 (133)	85,2 (122)	,590	
Bridging	100 (14)	93,9 (124)	97.7 (133)	100 (122)	,008	,153
Remember	74 (990)	90,8 (315)	91.6 (631)	89,9 (595)	<,001	,225
Understand	85,7 (28)	86,3 (204)	88.1 (201)	90,8 (195)	,545	
apply	66,8 (277)	47,1 (17)	68 (128)	81,6 (98)	,008	,151

Table 39 subject "steady state" test scores and chi square tests

Subject or Bloom's taxonomy level	*EUR*	*LEI*	*RU*	*VU*	*Chi-square significance*	*Cramer's V value*
Interaction	100 (14)	94,1 (34)	97,1 (68)	100 (73)	,139	
Indication	75,1 (943)	84,3 (115)	86,2 (494)	86,9 (465)	<,001	,144
ADME	45,6 (136)		82.6 (132)	84 (106)	<,001	,393
Antidote	71,4 (14)	83 (94)	83.5 (133)	85,2 (122)	,622	
Bridging	100 (14)	95,7 (94)	97.7 (133)	100 (122)	,061	
Remember	73,4 (816)	89,5 (209)	91.6 (631)	89,9 (595)	<,001	,228
Understand	85,7 (28)	85,9 (128)	88.1 (201)	90,8 (195)	,563	
apply	66,8 (277)		68 (128)	81,6 (98)	,019	,126

For the next tables only Cramer's V values are shown for statistically significant differences. No value means that the chi square test was not significant. In the multiple 3 medical school chi-square tests, the top shows the medical school that was absent in this analysis. W/O EUR, means the chi square test was done with LEI, RU and VU.

Table 40 multiple 3 medical school Cramer's V values

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall		,201	,203	,189
Interaction			,177	
Indication		,134	,126	,120
ADME	LUMC absent	,343	LUMC absent	LUMC absent
Antidote				
Bridging	,150		,178	
Remember		,224	,210	,228
Understand				
apply	,211	,126	,174	

Table 41 multiple 3 medical school Cramer's V values in steady state

Subject or Bloom's taxonomy level	*W/O EUR*	*W/O LEI*	*W/O RU*	*W/O VU*
Overall		,208	,214	,198
Interaction				
Indication		,146	,137	,131
ADME	LUMC absent	,393	LUMC absent	LUM absent
Antidote				
Bridging	,119		,160	
Remember		,232	,211	,232
Understand				
apply	LUMC absent	,126	LUMC absent	LUMC absent

For the next tables only phi values are shown for statistically significant differences. No value means that the chi square test was not significant.

Table 42 One versus one Phi values

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall Interaction Indication	,162	,182	,200			
ADME Antidote Bridging Remember Understand apply	,078	,117	,123			
	LUMC absent	,319	,322	LUMC absent	LUMC absent	
					,173	
	,173	,218	,192			
			,143		,289	,154

Table 43 One versus one Phi values in steady state

Subject or Bloom's taxonomy level	*EUR/LEI*	*EUR/RU*	*EUR/VU*	*LEI/RU*	*LEI/VU*	*RU/VU*
Overall Interaction Indication	,158	,192	,211			
ADME Antidote Bridging Remember Understand apply	,068	,130	,136			
	LUMC absent	,385	,393	LUMC absent	LUMC absent	
					,156	
	,153	,232	,205			
	LUMC absent		,143	LUMC absent	LUMC absent	,154

8.3. Appendix C: curriculum mapping.

Curriculum mapping of the bachelor with names of courses in which anticoagulation education is taught as primary or secondary focus.

Curriculum mapping of the master with names of courses in which anticoagulation education is taught as primary or secondary focus