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Innovative Maritime Design Education at NHL Stenden University of Applied Sciences

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ABSTRACT

The digital and energy transition will change our industry. To be prepared for this challenge, NHL Stenden University of Applied Sciences puts quite some effort in developing new innovative courses and new types of digitally enabled education. An example is a new minor concentrated on engineering tools and methods that have emerged in the (construction) industry over the past decades. In addition, the school is also working on a game to educate an old trade: ship stability. In addition to the changes to the existing programs, a new level of education is introduced in the Netherlands, the Professional Doctorate. The Professional Doctorate is comparable to the PhD but focusses on practically applied research. All these changes and innovations to the current maritime education at NHL Stenden are elaborated upon in this paper. The paper concludes with an outlook to the future, based upon the results from a survey held under students and lecturers regarding their view on the future of maritime education. The results of this survey show that especially green and modern propulsion methods are underexposed in the current curriculum.

KEY WORDS
Maritime Education, Professional Doctorate, Maritime Bachelor, Education Innovation

INTRODUCTION
In the Netherlands, higher education is split into two parts, traditional universities and Universities of Applied Sciences (UAS). Traditionally, universities focus on the fundamentals both in education and in research; design theory and design methods and fundamental research are key. UAS are focused more on the practical application of both research and the skill required by students. However, for most engineering studies, the lines sometimes get blurred.

This article discusses several innovations and adaptations that have been made at the NHL Stenden UAS both in the bachelor and master programs. It discusses how the changes are implemented and what the effect is on the education. Finally, a new level of education, the professional doctorate is discussed. The article starts with an explanation of the Dutch higher education system and a short introduction of the maritime education at the NHL Stenden UAS.

European Qualification Framework
In 2008, the European Union set up a European Qualification Framework (EQF) to streamline the different education systems within the EU and several neighbouring countries (European Union, n.d.). The EQF consists of 8 levels of learning, starting from a lower secondary school level at level 1 to doctoral degree level at level 8. Higher education covers levels 6 – 8, as is shown in Table 1.

Table 1 Overview of EQF levels for higher education (European Union, n.d.)

EQF level	**Degree**
6	Bachelor degree
7	Master degree
8	PhD or Professional doctorate

For each level of education, the European union has set up learning goals. The individual member countries, as well as several other neighbouring countries have adjusted their national education framework to match the learning goals stated in

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the European framework. This makes it easier for students from one country to study in another country (European Union, n.d.), as levels are comparable and easily translated. It also allows future employers of the students to better understand their qualifications and capabilities.

However, as with many overarching systems that try to integrate many different systems, the EQF levels do lead to some interesting situations in the EU member countries. Therefore, it is important to also understand the intricacies of the Dutch higher education system.

Understanding the Dutch education system

In the Netherlands, students are sorted into different tracks of secondary school after finishing their primary school. Which track they finish determines which continued education they have access to. After high school, students enter either vocational education or higher education. The Dutch higher education system is a binary systems consisting of 14 universities and 36 UAS (Vereniging Hogescholen, 2021). In total, well over 800.000 students were enrolled in either type of education in 2020 (Centraal Bureau voor Statistiek, 2021). A basic overview of this is shown in Figure 1.

The Dutch universities offer a bachelor degree, a master degree and a PhD. UAS also offer a bachelor degree, lasting four years instead of the three years of a university bachelor degree. Additionally some studies offer a master degree, although often set up as part time study to allow students to combine continued education with their career (Nuffic, n.d.-a). However, even though the degrees and titles students gain at the end of their studies are the same, they are not free to transition from an UAS to an university without taking transitional courses. These transitional courses sometimes require an additional year of education.

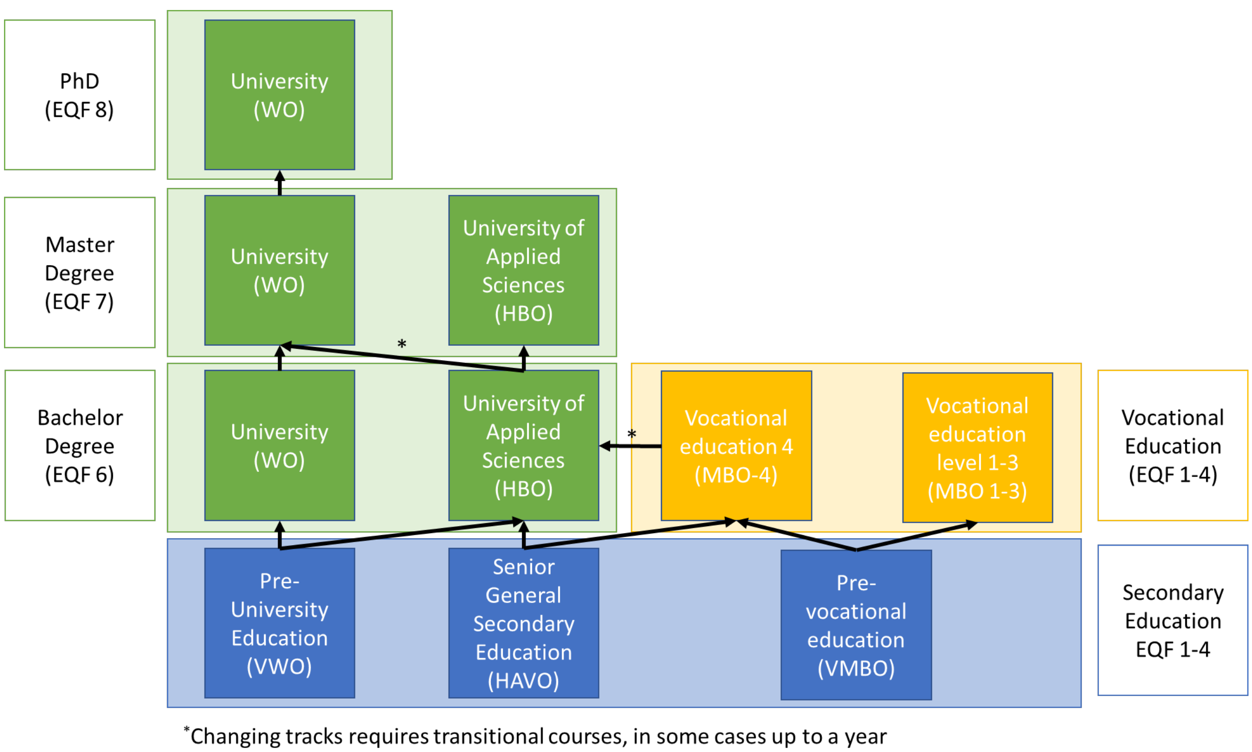

Figure 1 Simplified overview of the Dutch education system including some of the different changes possible between tracks based on (Nuffic, n.d.-b)

At both the university level and the UAS level students are taught research skills and have to perform several research projects to successfully finish their degree. However, above student level, UAS' only perform limited research activities at the moment. Universities on the other hand combine research and education activities. The research performed at UAS level, by both students and researchers is more practical in nature, focusing on direct applicability for the society or industry, whereas research at universities is more theoretical, focusing on, for example, methodology and theoretical foundation.

ARTICLE SET-UP

This article introduces several recent changes made to the maritime technology education at the NHL Stenden UAS. The article is split up in four parts. First, the set-up of the maritime education the students receive now is presented. After that, the recent, and upcoming changes in the bachelor are elaborated upon. After that, the professional doctorate, a new EQF level 8 educational track is discussed. Finally, the article ends with research into upcoming changes that both students and lecturers deem important.

STUDYING MARINE TECHNOLOGY AT NHL-STENDEN

“Maritiem Instituut Willem Barentsz” is the maritime institute of NHL Stenden University of Applied Sciences, with four-year BSc education in Marine Technology, Master Mariner and Ocean Technology, as well as an MSc course in Marine Shipping Innovation (NHL Stenden, 2021).

In the BSc Marine Technology students are taught mathematics, physics, ship design and construction, marine engineering and several other smaller courses on subjects such as maritime law and economics, English and research and management skills. This four year curriculum is presented in more detail in Figure 2. Here the courses in yellow are mathematics courses, orange represent the (general) physics courses, dark blue are maritime theory courses, green are soft skill courses and the turquois are maritime project courses. As can be seen, during the four year BSc the first year is meant for 60 ECTS filled with courses. In the second period of the second year there is a 15 ECTS workplace internship, where the students are supposed to get hands-on experience with ship production. The other 45 ECTS of the second year are again made up of courses. In the first period of the third year there is again an internship, however this internship is not at a workplace but preferably at a ship design company/department. The goal of this internship is for the students to put their ship design skill into practice. In the rest of the third year there are 15 ECTS of elective courses, which can be chosen by the student to be either more in-depth or more broadening. Next to the elective subjects and the office internship, the rest of the third year is made up of regular compulsory courses. The last, year is reserved for first an elective minor and second the thesis research, which concludes the educational program.

The bachelor program Marine Technology starts with fundamental courses in mathematics and (maritime) physics, as also illustrated in Figure 2, however later in the program there comes more and more time and space for the students own interests, in for example the elective courses and the minor. Furthermore, with the two different internships during the program the students know what is happening in industry and are really ready to enter the maritime industry after completion of the BSc program.

Next to this BSc program, the MIWB also has a MSc program; the Master Marine Shipping Innovation (MMSI). This master is unique in the Netherlands as it is the only maritime master that focusses on maritime professionals that want to expand their knowledge and learn to innovate. Students have several years of industry experience and therefor bring with them their own expertise and knowledge. A trade they share with most their lecturers, who also combine their teaching job with an additional job in industry. The maritime sector has a need for highly educated people who can innovate based on their operational expertise. This is necessary now more than ever, to address the current sustainability challenges the maritime sector is facing.

The master is part-time, where 60 ECTS are spread over two years, meaning the students do the master in addition to their existing job. The master offers on-demand education, where students can select from a wide range of subjects to further expand their knowledge in three different tracks being; Nautical, Technical and Design. Once every ten weeks, all student get together for a week full of education at the MIWB at Terschelling. There are five of these so called “contact weeks” per academic year, where there are lectures, workshops and students present their innovation, this means that remaining weeks of the academic year the students are free to allocate their own time. As the students study part-time, their newly acquired knowledge (for example in data science or new engineering tools) is transferred immediately back into industry, and the innovations that the students develop, directly benefit their own company. Because the students come from all kinds of different fields within the maritime industry, the students not only learn from the lectures and courses, but also gather a lot of relevant new insights from the contact with each other.

Now that we have hopefully made clear what studying marine technology at NHL Stenden University of Applied Sciences, at either bachelor or master level, entails. In the next sections we would like to elaborate upon the changes we are currently making to keep our education up-to-date and relevant. As the world is changing, we need to prepare the engineers of the future for this future and not for the past. This means we need to expand and adapt our current curriculum, but doesn’t necessarily mean we can replace existing courses. How we are trying to keep up with the world in transition, without compromising the time required for the fundamental mathematics and (maritime) physics courses is outlined in the next part.

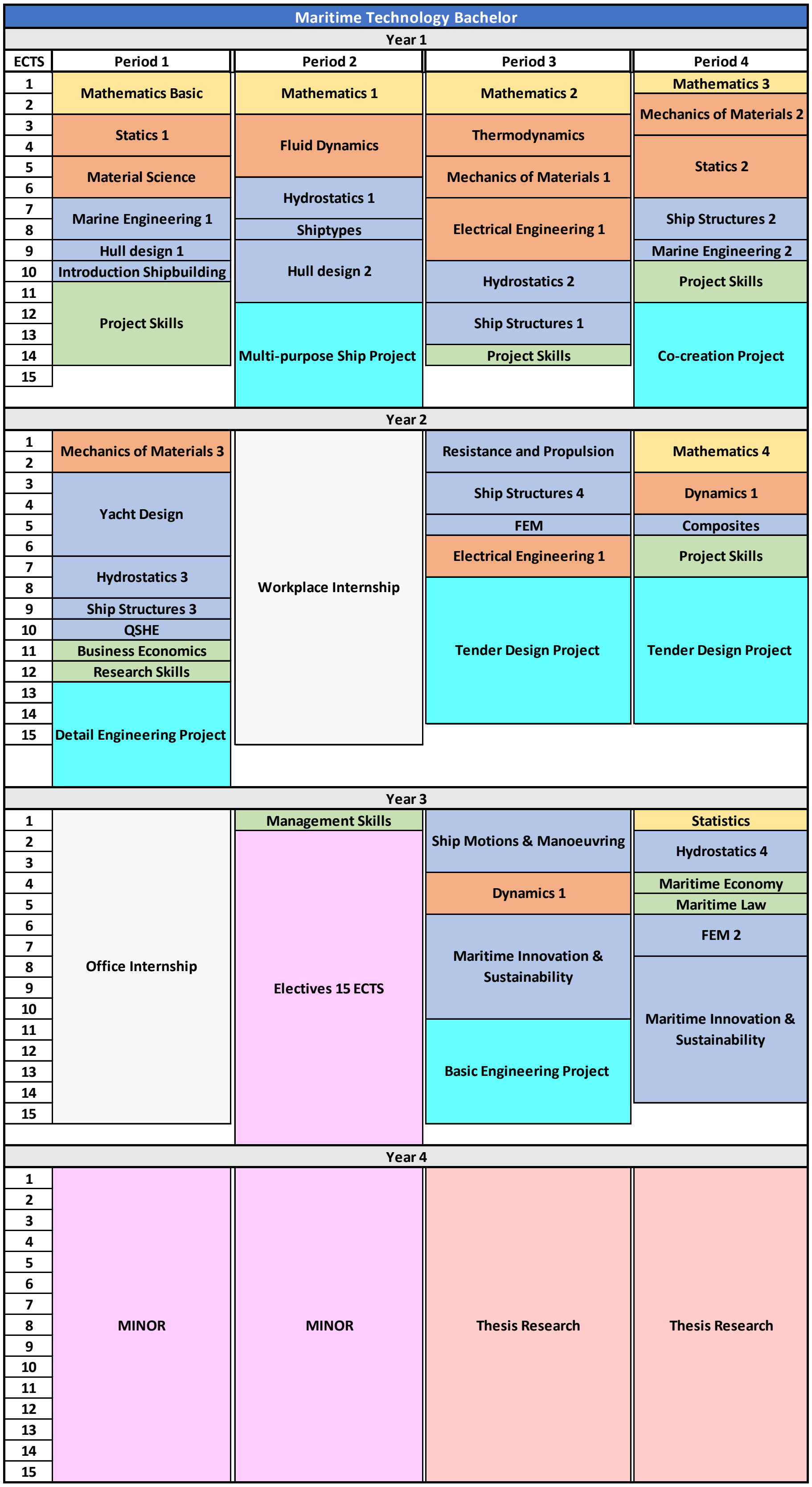

Figure 2 Overview of the BSc Marine Technology at MIWB

INNOVATIONS IN THE BACHELOR

Big data, ubiquitous computing, neural networks, Internet of Things (IoT), sensors and sensor networks are the buzz words of this age. Popular media, business journals and scientific papers are cramped with reports on the phenomena and their expected future advancements. Yet, with "Applied" in the name of our institute, philosophising or dreaming of a bright new world is not enough. Therefore, several steps have been taken to adapt our bachelor. Two of these steps are presented in this paper, not only with the objective to inform, but also to identify opportunities for collaboration.

Minor Advanced Engineering Tools for ShipX

One manifestation is the BSc minor "Advanced Engineering Tools for ShipX" (AETS), where X is shorthand for design, operation and/or management. In courses of ship design and engineering the particulars of the profession are well-taught. However, driven by software and computer advancement, in the industry over the past decades new tools have emerged, such as optimisation, geometric modelling, CFD, big data and machine learning. These tools have been considered too complex for an undergraduate program. Yet, some knowledge of this trade is essential on every professional level, and our proposition is that if the material is offered in a first-principle fashion, in combination with practical exercises and oral discussion, the heart of the matter can very well be educated to an undergraduate. In this fashion the 30 ECTS bachelor minor AETS was developed.

Set-up of the Minor

The first semester of the fourth BSc year is allocated for a 30 ECTS (at 28 hours/EC, corresponding to 840 hours) elective minor. The AETS minor was first offered in September 2020, this first year the minor was only available to MIWB students. Yet, in September 2021, the minor was offered for the second time and is now open to all students with a technical background and an interest in the maritime world. Furthermore, the minor is also offered as a postgraduate course to professionals in the field. The courses are taught with introductory lectures, references to relevant literature, and assignments, many assignments, which are performed in alternating groups of two or three persons. Deliverables consist of reports, working computer programs, presentations and an occasional podcast. The minor consists of the following seven courses:

- **Programming in Python -** 4 ECTS,
- **Numerical Methods in Engineering** - 3 ECTS,
- **Optimization Methods** - 3 ECTS,
- **Data and Shape Modelling** - 5 ECTS,
- **Application of Computational Fluid Dynamics (CFD) -** 4 ECTS**,**
- **Introduction to Data Science** - 5 ECTS,
- **Research Assignment** - 6 ECTS.

The minor is concentrated on engineering tools and methods that have emerged in the (construction) industry over the past decades. Because quite some tools are implemented in software, the minor starts with a programming course, as can be seen in Figure 3. However, the emphasis of the minor is not on programming, but on algorithms and algorithmic thinking. For programming languages come and go, while smart algorithms remain to serve us for centuries. There are (too) many programming languages in circulation, while in essence they all do the same thing. Seen from a distance, one language is not better than the other, just like Spanish is not better or worse than French. We have a preference for elegancy, which causes 85 percent of the languages to be abandoned. Other indicators are popularity and low-cost, and, predominantly, the availability of a wide collection of pre-programmed libraries with all kinds of utility functions. Based on these criteria Python has surfaced.

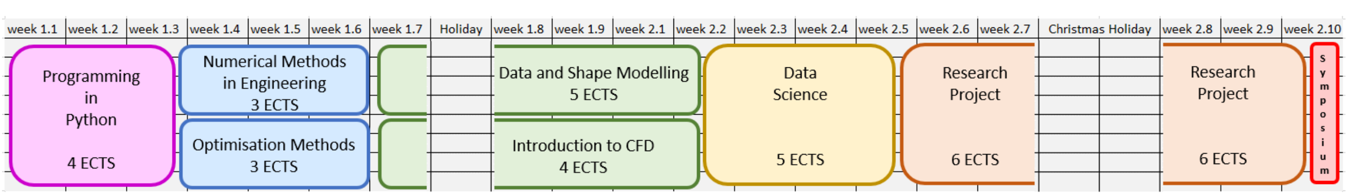

Figure 3 Set-up of the AETS Minor

The aim of the Python course is to provide the students with a practically useful tool. In this respect Python is superb; it is generic, elegant, supported by a vast amount of resources (forums, books, a nice learning app; Sololearn) and a plethora of libraries with all kinds of tools and functions for mathematics, numerical analysis, text processing, file management, data analytics, AI etcetera. It may be obvious that just four EC is insufficient to educate seasoned Python programmers. But that has never been the goal of this minor. Programming skills up to the level of numerical operations, functions, file I/O, simple graphs and the usage of external libraries are sufficient, for now.

In Numerical Methods for Engineering, maritime applications of differential equations and statistics are treated. However, not from a theoretical background, but practice based. An illustration hereof is the exercise of the heave motion of a vertical cylinder. The standard textbook solution requires some mathematical skills, resulting in the well-known logarithmic decrement. However, with Newton's second law and numerical integration in small time steps the solution is also found. And not with less understanding, because that is not in the mathematical analysis, it is in internalizing F=m.a, and its power in practice. After this exercise, the student is gently reminded that the analytical solution is only valid for linear cases, while the numerical one is universal. This exercise can be found in the appendix.

In the 3 ECTS course Optimization Methods, there is not enough time to explore and explain all optimization methods available within the field of operational research. We have chosen to only cover linear programming and non-linear optimization. This because most appealing examples from the maritime field are non-linear problems and one needs to understands the linear programming concepts before starting with the non-linear optimization. Thus, in this course we start with relatively simple linear programming exercises before elaborating the more fun topics such as, resistance minimization, propellor optimization, collision avoidance, weather routing and fleet optimization. An example of a weather routing exercise is presented in the appendix.

Data and Shape Modelling seen from a distance, may seem a odd combination, however, the two are different applications of the same tools. In data modelling for example a regression formula or another meta model is fitted through data points. And for ship hull shape modelling similar tools are used to fit a smooth hull surface through measured points. The data modelling part contains exercises with linear least squares regression, applied on 2D and 3D linear as well as 2D polynomial functions. A non-programming exercise was the modification of a vessel's bulb shape, with a dedicated hull shape modelling program, Figure 4. This ship was the same as subsequently used for CFD, and as an intermediate step a physical model was prepared for 3D printing, Figure 6.

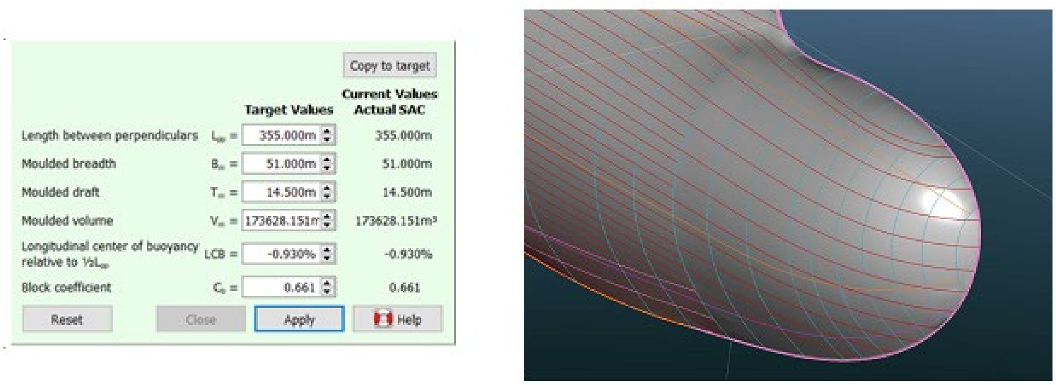

Figure 4 Bulb Shape Modification Exercise

The 4 ECTS CFD course, only allows us to teach the very first principles of stationary flow around the hull, and the related resistance. To students with basic knowledge of fluid flow around the hull, resistance components, shallow water effects and empirical estimation methods for resistance, but without prior exposure to potential flow or Navier-Stokes. In order to teach the students a practical application, a full-blown commercial CFD program was chosen for these exercises. In this case STAR-CCM+, by Siemens. One of the reasons for this choice was the associated extensive helpdesk support as kindly offered by Femto, (www.femto.eu). With the assistance of an external tutor, (www.sastech.nl), an achievable goal was formulated; that at the end of the course the student is capable, in her or his role as ship designer, to order a CFD calculation with an external specialist, and to be able to understand the reported results and conclusions in a responsible manner. Thanks to hard work of the students, in this short time span they independently managed to produce reliable results, Figure 5.

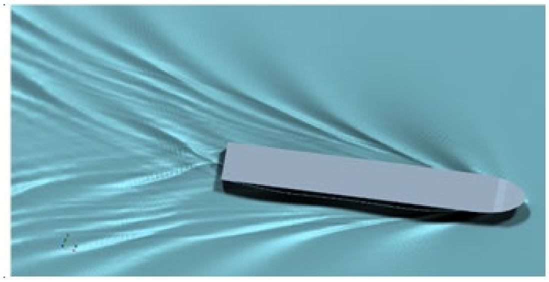

Figure 5 Example of a Student's Result After Two Week of CFD exercises

Introduction to Data Science is a little bit the odd one out. Until now the emphasis was on algorithms and programming, but here a number of speakers from the industry were invited to present their vision, developments and achievements. With the idea to build a bridge between theory and practice. Yet, this course also contains a programming assignment, or actually a competition, where a (moderately polluted) database with all kinds of general particulars of 13,000 ships was supplied. The task was to learn an algorithm to derive the ship type from its particulars. The winner is the group with the highest score on a separate test set. A single ECTS from the data science course has been dedicated to normative aspects of algorithms, data(collection) and AI. Here some papers and podcasts have been supplied, with the student's task to reflect and report, also in a podcast, on two (selected from a list of supplied) propositions.

The minor is concluded with an individual Research Assignment where the student demonstrates the ability to apply the learned tools in a practical maritime application. The students can choose a subject of their own interest to which they have to apply some of the content they learned during the minor. This resulted in a very diverse range of topics:

- Optimization of frame spacing for minimum weight,
- CFD analysis of propellor nozzle with and without anodes,
- Application of Neural Networks in Ships' Autopilot settings,
- Track optimization in an Yngling sailing race,
- Optimization of ship routes in extreme waves,
- Travel time optimization of sailing routes at the Waddensea,
- Using a kite for wind assisted propulsion of a cargo vessel,
- CFD optimization of hull form in shallow water,
- Machine Learning to predict resistance,
- Predict the effect of wind on fuel consumption.

This course and therewith the whole minor are closed with a short paper and a mini symposium, at which the students present their research and results to each other, a jury from industry, other students from the maritime bachelor and their family and/or friends. Afterwards the jury selects and awards the most innovative research project.

Figure 6 Group of AETS Students Proudly Presenting their 3D Print

Evaluation of the Minor
The governing learning strategy is to minimize the use of too complicated mathematics where possible, and to rely on elementary physical or mathematical mechanisms instead. For example, a planar moment of inertia (I) is usually educated using Steiner's theorem, which in its turn is derived by analytical integration. Our proposition is that by this detour of integration + theorem the insight into the heart of the matter is obfuscated. While the essence of I is simply the summation of every tiny piece of area multiplied by the square of its distance from centroid. Cumbersome to compute in this fashion for a human, but for a computer only a trifle. Such a 'first principle' approach illuminates the essence, while the use of previously derived "theorems" only obscures it. In this sense there is an analogy with "object lessons" (Dutch "aanschouwelijk onderwijs", German "Anschauungsunterricht"), a concept attributed to Comenius (1592 - 1670) (Comenius & Hoole, 1700). Its original implementation was that in addition to language (Latin, in those days), objects or visuals may serve better for students to receive or discover ideas. The correspondence is that also in our view the language of higher mathematics is not always the best instrument to transfer knowledge, for our audience.

The minor AETS was recently given for the second time, and was again quite successful. Both students and lecturers were very positive for the second year in a row. '*A nice enrichment of the existing curriculum*' says Jan de Jonge, MIWB lecturer about the minor. And finally, we do not want to leave unmentioned a few remarkable quotes and remarks from the student survey:

- "Hold on and be patient, it's all going to be fine." (to students in the next curriculum)
- "A spreadsheet does your calculations. A programming language does your thinking."
- "If I had to choose a minor again with the knowledge I have now, I would definitely choose this minor again. It is a very future-oriented minor with an in-depth knowledge of mathematics, but also the CFD and data science courses are very useful for the future. We now have a basic knowledge/acquaintance with these techniques that classmates of mine do not have."

Stability Game
The second manifestation to adapt our bachelor curriculum is the development of a stability game. This to make time and space for new courses (for example courses about the new tools and programs as explained before) in the curriculum. In order to create time for a new course, other courses should either be abolished or taught more efficiently.

A candidate for rationalisation is the course on ship stability. This choice may be somewhat unexpected, for one of the authors is a renowned stability expert. Yet, our aim is not to drift away from stability as such, on the contrary, the idea is to focus on the essentials of stability. Quite a challenge, because our rich maritime history obfuscates the essence of stability. Which is – limiting ourselves to the timeless action of forces and moments under heel, as reflected in the IMO Intact stability code and many other stability rules and guidelines – the perpendicular distance between the downward force through Centre of Gravity, and the upward force through Centre of Buoyance, Figure 7. Is that all there is? Yes, that's all there is.

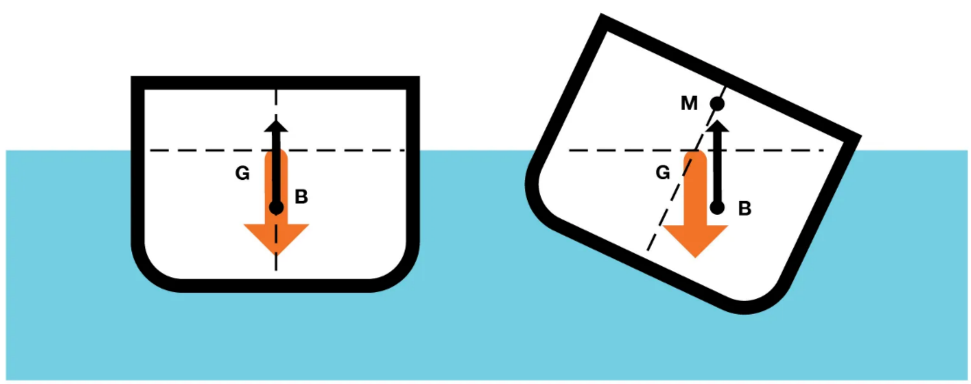

Figure 7 Illustration of the Basic Concept of Stability (The Editors of Encyclopaedia Britannica, n.d.)

Unfortunately, the clear view of this foundation has been taken away from us because calculating stability was once (by hand) so time-consuming. For this reason, we have been buried with all kind of side dishes, such as Simpson's rules, moment to change trim, GM = KM – KG, tonne per centimetre immersion, et cetera. Not incorrect, once useful, but now obsolete because arithmetic is not a limitation anymore. The *raison d'être* of the metacentric height is its linear approximation of GZ – the righting lever – around zero degrees. But why use an approximation if an exact computation is so easy to obtain? Scribanti provides a higher-order polynomial approximation around zero degrees. Again, why approximate? By the way, both are special cases of the Taylor expansion, a generic tool taught over the past fifty years at first year university math courses. Plain stuff, so there is no need for specific traditional naval architectural concepts or notions. So, if we scupper such forlorn concepts, then we return to the basics; the distance between downward and upward forces, depicted as function of heel in the GZ-curve. That's all there is.

Figure 8 Screenshot at the Start of the Race in the Stability Game, with the stability curve at the top right

Until now, this spirit on this subject has been a bit destructive, however, if old forms and thoughts have died, what to use as replacement in the education in stability? Experiments with a physical model have been considered, at model scale in a water basin, or with larger models on open water. Besides the human risks involved with open water experiments, a physical model has the drawback that the essence of stability, the effect of the forces, is not visible or otherwise perceptible. So, another instrument for displaying these notions was sought, and found in the guise of a computer game. The scenario of the game is a race between two different vessels, going around several small islands. To win the race you have to, finish first and stay between the navigation marks, during the race you will experience, different kinds of water depths closer of further from the islands, and varying weather conditions. Before starting the race you can choose your own vessel, the vessels differ in length, beam, draught, loading capacity and thus stability. This starts as a skill game, but becomes educational because the stability forces and stability curve are also shown at the top right of the screen, as can be seen in Figure 8. Figure 9 shows a vessel and corresponding stability curve in normal condition at the lefthand side, and a more heeling vessel with corresponding effect on the curve on the righthand side.

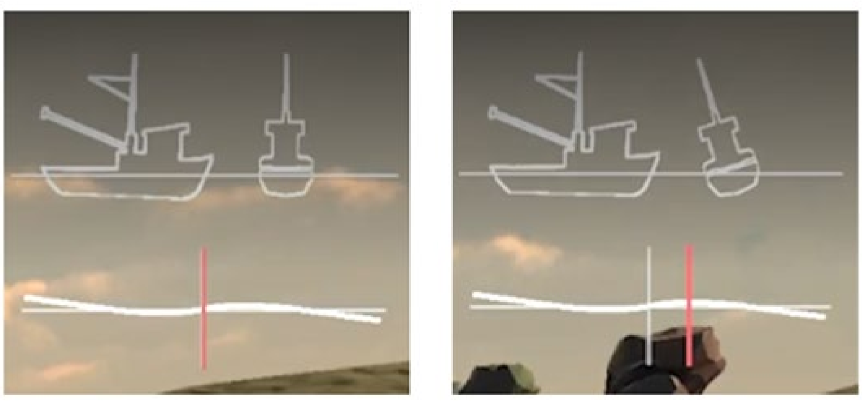

Figure 9 Detail of Stability Curve at Two Different Moments

During the game the students experience the effect of the ship's construction and cargo, in the behaviour of their vessel and the corresponding stability curve at the top right. Adding elements to the vessel, such as outriggers or a crow's nest, has an effect on the ships stability. Figure 10 shows some of the possible elements added and their effect on the stability curve. The whole idea behind this game is that from experiencing the primary behaviour of the vessel and this additional play of forces, an established concept of stability arises in the student. Obviously, afterwards the theory will have to be elaborated a bit more, and one will have to practice with calculations, but first comes the understanding and only then the math. Important building blocks of the game – which is being developed with support of Stichting Verolme Trust – are currently completed, such as the entire scene with islands, the "construction site" for choosing the different vessels and the underlying stability calculator. Completion of the first playable game version is expected later this year.

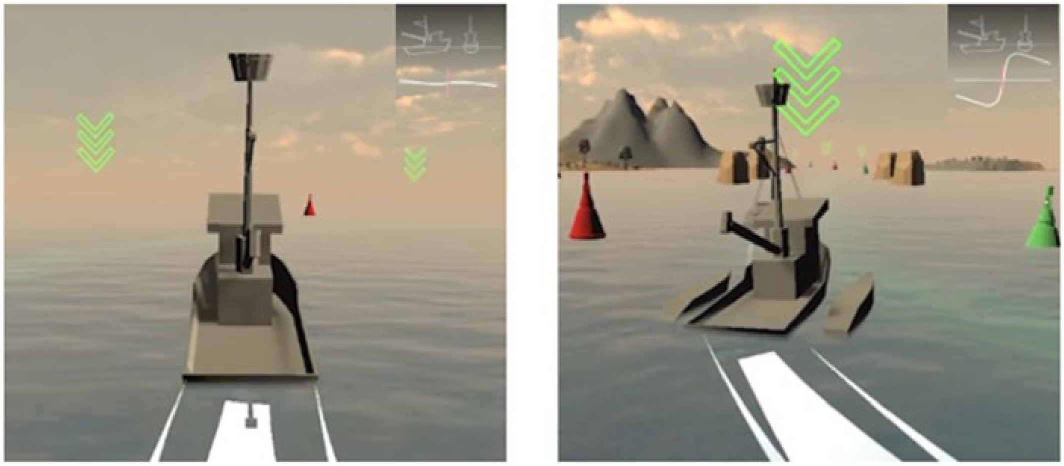

Figure 10 Illustration of Vessel in the Game with Different Elements Added

INTRODUCING THE PROFESSIONAL DOCTORATE

As mentioned, research at traditional universities focuses mostly on the fundamentals, investigating design methods and design tools while research at the UAS is more practical in nature. Engineering in general and the maritime industry specifically is very practical and the application of research is of high interest to the industry. Currently, there is a gap in the wish of the industry for more applicable research and the requirements for a PhD. Since the introduction of the Bachelor - Master structure in 2002 it has been suggested that UAS's should also be allowed to offer the third cycle of higher education (i.e., a PhD program). However, this is currently not allowed by law (Programmateam 3e cyclus in het hbo, 2021)

Compared to other Western European countries, the Netherlands has a relatively low number of students that chose to obtain a degree in the third cycle of higher education. This is shown in Table 2, which compares the number of students in each level of higher education for several Western European countries. By allowing UAS to offer a third degree, the numbers for students obtaining this degree could be increased.

In 2019 the Netherlands Association of Universities of Applied Sciences wrote a white paper together with the Association of Dutch Universities stating their plan to offer the PD at the UAS. Funding was made available, and in January 2023, 5 programs can start with a pilot. The goal is to set up an independent, internationally recognised third cycle of higher education, that is clearly different from a PhD offered by the universities. This is to keep in line with the Dutch binary higher education system (Vereniging Hogescholen & VSNU, 2019).

Table 2 Number of students in Higher education (thousands) and percentage of students that continue on to pursue a PhD or similar for selected European countries in 2018 (European Union, 2020)

Country	Bachelor degree or similar (EQF 6)	Master degree or similar (EQF 7)	Doctoral degree or similar (EQF 8)	Fraction of PhD students compared to Bachelor students [%]	Fraction of PhD students compared to master students [%]
The Netherlands	668.8	180	15.7	2.3	8.7
Belgium	372.7	102.8	17.3	4.6	16.8
Germany	1872.7	1054.5	200.5	10.7	19
France	1058.5	989.1	66.1	6.2	6.7
United Kingdom	1621	450.6	111.3	6.9	24.7
Denmark	195.8	70	9.4	4.8	13.4
Norway	199.2	72.4	8.5	4.3	11.7
Sweden	241	144.8	19.7	8.2	13.6

Comparing a PD to a PhD

In many ways the process of obtaining a PD is comparable to obtaining a PhD in the Netherlands. The candidates are expected to perform research in their field of expertise, leading to new knowledge, or a new process. They are also expected to follow some courses that further either their understanding of their subject matter or their professional skills. To obtain their PD, they are supervised by one or more supervisors from their UAS and practice. There are also some key differences, that are explained in Table 3.

Table 3 Overview of the differences between a PD and a PhD (Programmateam 3e cyclus in het hbo, 2021)

	PD	**PhD**
Definition of educational concept	Professional education that teaches a candidate to be a researching professional who can make improvements and changes to complex industries	Academic education that teaches a candidate to be an independent researcher capable of performing academic research
Results	Generic new knowledge regarding processes, products or actions that take place in complex industry settings	Generic new conceptual knowledge that adds to the scientific knowledge of the research area.
Admission	Admission is possible with a relevant master (UAS or university) and experience in the field of study.	Relevant master from a university
Final defence	Portfolio review	Public defence of written thesis

Societal benefit

The PD fills a gap between what the Dutch society wants and needs researched, and what universities currently research. By taking a more practical and applied view to research it is possible to apply practical knowledge to modern challenges. The PD offers an education for those who which to become proficient in applied innovation (Programmateam 3e cyclus in het hbo, 2021). In the Maritime sector, PhD projects are often already applied and more practical in nature. Current modern challenges such as the energy transition, the use of big data and unmanned and autonomous shipping require a connection to industry to be relevant and useful. However, university students often start a PhD directly after their master, without industry experience. However, understanding the complexities of implementing a new technology in our sector is exceedingly difficult without this knowledge. The PD is aimed at candidates that do have this industry experience and want to use this experience to further the sector. The combination of the theoretic knowledge at the universities and the practical and applied knowledge at the universities should strengthen each other in our sector.

Another large benefit of performing research at the UAS is that it will benefit education. By making the two different tracks of higher education more equal in terms of offered possibilities, students who follow the pre-university secondary education might be more enticed to choose for the UAS instead of a university. Currently, students who follow this education do not look at UAS as a serious option, however at the end of their bachelor a significant amount of students agree that they might have been better suited for a UAS.

Additionally, focussing more on research at the UAS might attract more lecturers who themselves have a doctorate, or in the future a PD. By allowing them to combine a teaching position with a research position, they support both the level of education provided and increase the research capabilities of the UAS.

SNEAK PEEK INTO THE FUTURE

The changes mentioned above are already underway. However, with so many new challenges that face the maritime industry further changes are likely to be required in the near future. To that end, a digital survey was held where students and lecturers of the maritime department at NHL Stenden UAS have been asked several questions on how they view their current education.

In the survey, a differentiation was made between bachelor students and master students and lecturers. Bachelor students where asked if they feel that the current bachelor curriculum prepares them well for their future career. Additionally they are asked how they see their future career. Finally, they are asked what subjects they feel should be added to the curriculum to improve the connection to the industry requirements. This final question is also asked to master students and lecturers. In total, 32 responses were given to the survey. Seven lecturers responded, as well as 23 bachelor students, distributed over the 4 years. Of the master students, only two responded, making it impossible to draw conclusions from that. The distribution of participants can be found in Figure 3. In the next section, an overview of the most interesting results of the survey are discussed.

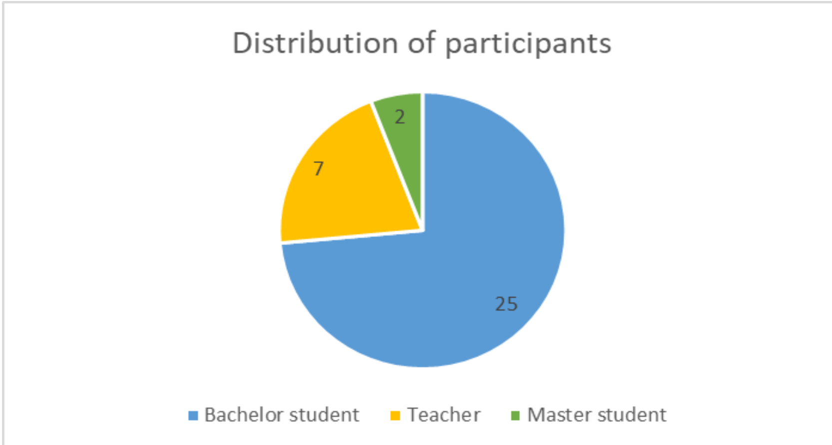

Figure 11 Overview of the distribution of participants

Survey Results

In this section, the most interesting results of the survey are discussed. First, the views of the students about their education in general is discussed. Next, a more detailed investigation is performed on how well the education fits with the requirements of industry. Finally, the wish for new or different subjects is discussed.

In the first two sections, aimed at bachelor students, the questions were asked using a Likert scale. The five point scale ranged from strongly disagree to strongly agree. For the answers to these questions an average and a mean can be determined, which can be used to make a more detailed analysis of the answers. The average is determined by assigning the value 1 to the statement strongly disagree, the value 2 to disagree, through to the value 5 for strongly agree.

Student Satisfaction

To get a general feel for how the bachelor students feel their education at NHL Stenden UAS meets the demands of the industry at the moment, the survey started off with four questions on this. The results of these questions are shown in Figure 4. This figure shows that in general, the students are reasonably satisfied with how well the curriculum addresses the general modern challenges and requirements of ship design. However, a significant number of students give a neutral or even negative answer to these questions. Both of the extremes are not given as answers for either of the first two questions. This suggests that changes that address more modern challenges could make the curriculum more appealing. Both questions have a mean of 4, showing a general agreement with the statement made. However, the average is only 3.5 for both questions, showing that while the general statement is that students agree, it is not a strong agreement.

When asked if their education places enough focus on green shipping and modern propulsion methods, there is a larger spread between the answers. A significant amount of students disagree with the statements that the curriculum addresses green shipping and modern propulsion methods enough. The is also expressed in the mean and average of the answers given. For the question related to green shipping, the mean is 3 and the average is 3.2. This is a neutral score, showing a significant possibility for improvement. For the question regarding modern propulsion methods, the mean is 3.5 and the average is 3.4, showing more agreement, but once again only slightly above a neutral score. This is interesting, as the bulk of the knowledge the students gain regarding this topic is covered in online one project, as becomes clear from Figure 2.

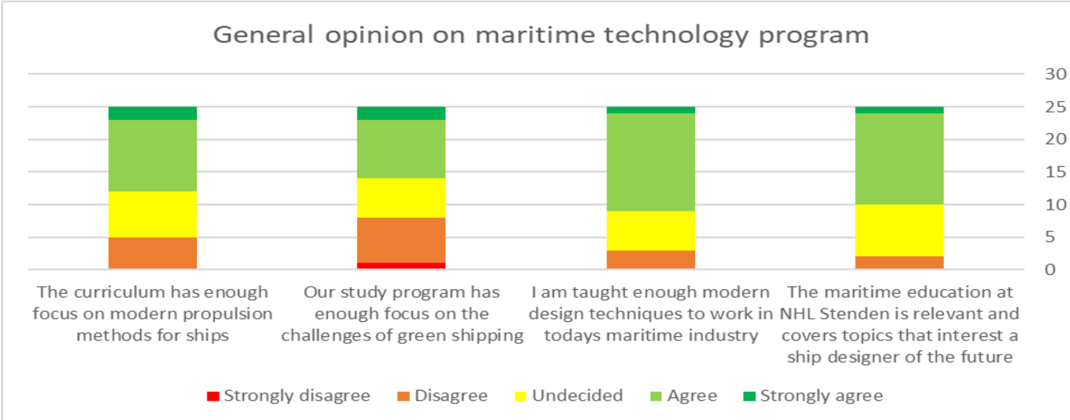

Figure 12 General opinion on the Maritime Technology program at NHL Stenden

As mentioned above, students take part in multiple industry internships over the course of their education. Therefore, the next questions focussed on how well the current curriculum matches with the requirements of the internships. For example, do they learn the right design methods and drawing programs for is there a mis-match. Therefore, students who answered that they had already completed at least one internship (17 students in total) were asked three questions on this subject.

The first conclusion that can be drawn from Figure 5 is that the design and drawing tools that the students are taught over the course of their studies matches well with the requirements of industry. Only three of the scores given are undecided or below, leading to a mean and average of 4, showing general agreement with this statement. The other two questions also have little to no negative answers given, leading to mean of 4 and an average of 3.5 and 3.6 respectively.

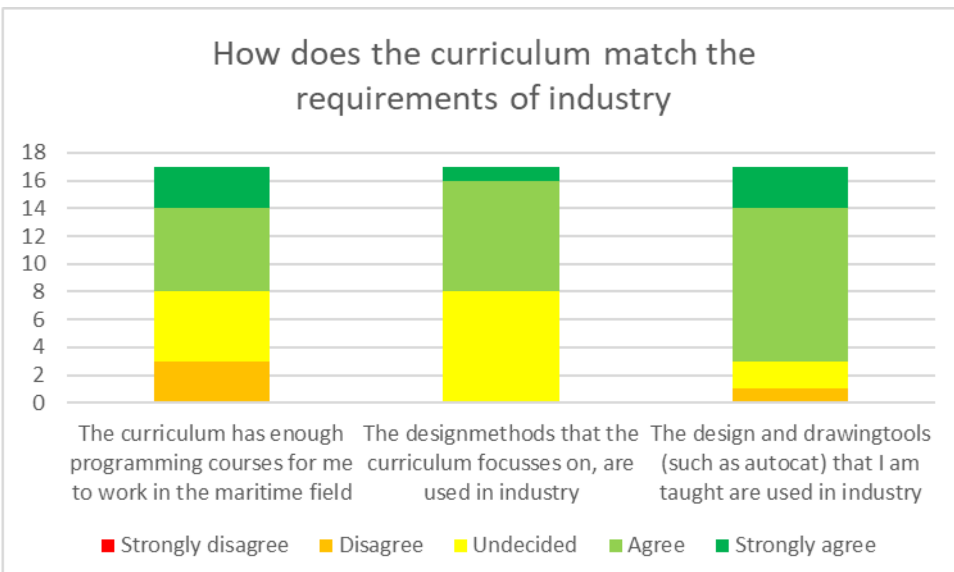

Figure 13 Curriculum versus the requirements of industry

New Courses

The second part of the survey was filled in by all respondents. This consisted of two questions, one asked if students and lecturers felt that topics that are currently of high interest in the maritime field would be a relevant edition to the curriculum. The second asked if they had additional subjects or topics that they felt would be an asset to the modern ship designer or maritime professional. The answers to the first question can be found in Figure 12 and Figure 13. In the second question, respondents were asked for input on subjects that they feel are missing from the list.

The subject that both bachelor students, and lecturers and master students feel would benefit the curriculum is propulsion methods of the future. In this case, a general subject covering different types of modern propulsion is preferred, as the separate subjects focussing on fuel cells, batteries and wind-assisted propulsion are all less popular. In the comment section, two respondents mentioned that alternative fuels are not mentioned in the list, but would be a valuable addition too. Finally a respondent stated that it would be interesting to have the students work on determining the best type (or types) of propulsion for their ship. Have them take the lead in finding a good solution over offering up ready-made solutions. The popularity of this subject is somewhat in contrast with the answers to how well modern propulsion methods are addressed in the curriculum.

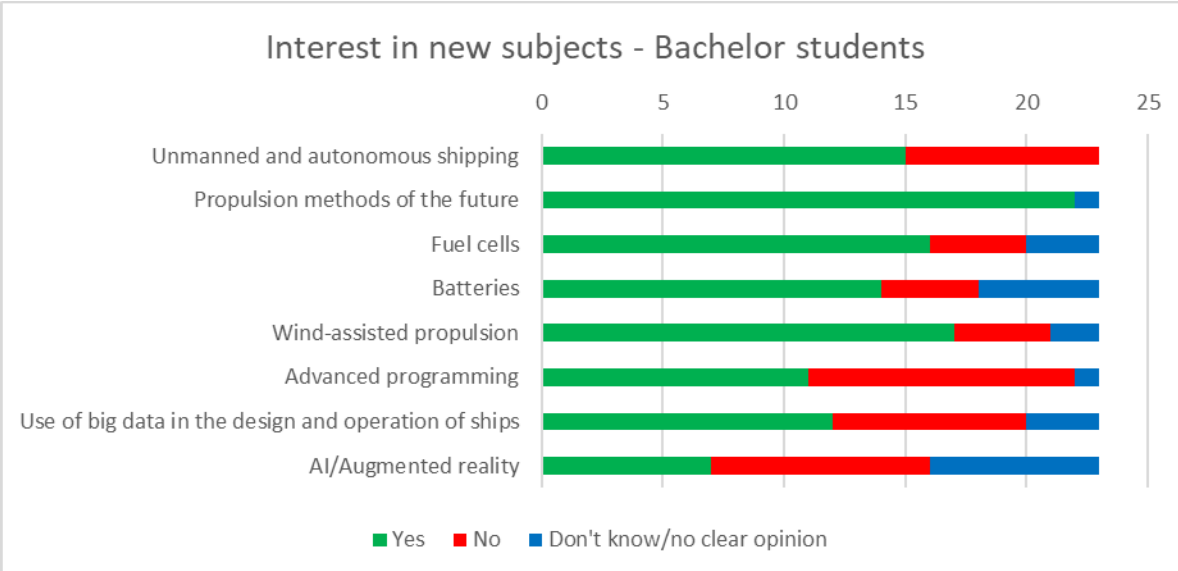

Figure 14 Responses to the list of potential new subjects - bachelor students

The next most popular subject, especially under lecturers and master students is unmanned and autonomous shipping. While 8 out of 9 lecturers and master students would see this as an interesting subject, 8 out of 23 students say that they would not be interested in this subject. A same sort of discrepancy is seen when talking about the use of big data in the design and operation of ships. Collecting data on ship operation and even design is a growing market. The possible benefit of this is recognized by the lecturers, of whom 7 see the benefit, while two reply don't know/ no opinion. On the other hand, the students are a lot less positive, with only 12 or of 23 students saying that they would be interested. This might be due to students not clearly seeing the benefit of this subject for their education.

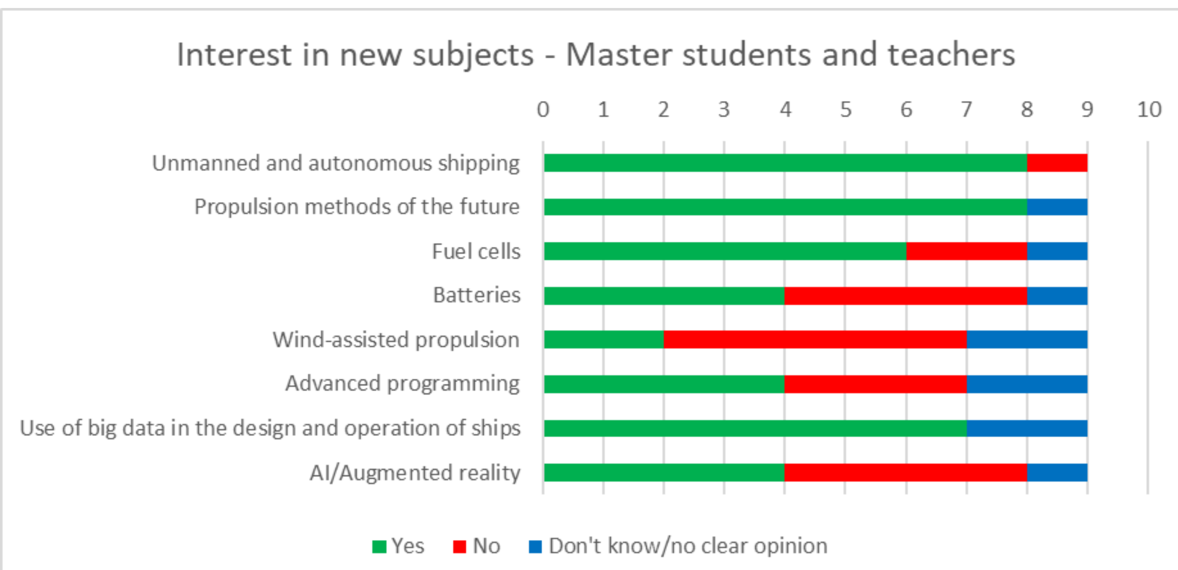

Figure 15 Responses to the list of potential new subjects - lecturers and master students

Both students and lecturers are not interested in an advanced programming course. While this is not a significant portion of the curriculum now. However, one of the lecturers does suggest that a basic programming course would be required before offering the students an advanced course.

From the open questions, several other subject suggestions were made. These were; more computational fluid dynamics calculations, foiling used in yacht design, cradle to cradle design, modern ship building and production methods, public awareness and cultural awareness for ship builders, a more direct link with the nautical school also attached to NHL Stenden UAS to learn more about the use of the ship and as mentioned previously, a basic programming course and the use of alternative fuels. In further research, for example when overhauling the curriculum, it would be interesting to investigate what students would think of these suggestions.

CONCLUDING REMARKS

This article introduced the maritime education at the NHL Stenden University of Applied Sciences. Several strides are made to make changes to the traditional curriculum of maritime education. By changing the way that students obtain knowledge, adapting the curriculum to meet the demands of the modern industry and introducing a new education level the curriculum, the students and the lecturers remain well rounded and highly skilled.

Students and lecturers alike see possibilities of further improving the curriculum by adding more courses that address modern challenges. Green propulsion, use of big data in design and operation of ship and unmanned and autonomous shipping are all subjects that they feel would be an enrichment of the curriculum. Although students generally feel that their studies prepare them well for a career in the industry, they also feel that especially green shipping and modern propulsion are underexposed at the moment, so adding these topics could be valuable. Currently, the curriculum is being reviewed, next to exploring the suggestions made by the students and lecturers, a network of companies has been setup that investigates the possibilities of new courses on robotisation and alternative fuels for the shipping industry. Altogether, the changes being implemented now and in the near future, in the maritime education at the MIWB, help to prepare up-to-date and industry-ready maritime young professionals.

ACKNOWLEDGEMENTS

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APPENDIX

DE1 Heaving cylinder

The motion equation of the oscillating vertical cylinder in —still and fresh — water is the familiar

$$(m+h)\,\ddot{z} + b\,\dot{z} + c\,z\; = 0 \qquad (1)$$

where the dot indicates a derivative taken with respect to time, *m* is the mass of the cylinder, *h* the hydrodynamic mass (added mass), *b* the damping coefficient and *c* the restoring coefficient (a.k.a. spring constant). Each term of this differential equation represents a force, and to put it completely, the downward force resulting from the mass of the cylinder (m.g) should also be included, however that is nullified by the upward force of the buoyancy (thanks to Archimedes' law). So, for the sake of brevity, these terms are left out.

In the simple case that b = 0, this equation transfers to the familiar undamped mass-spring equation

$$(m+h)\,\ddot{z} = \; -c\,z \qquad (2)$$

in which we recognize Newton's *F*=*m.a.*

The first task now is to internalize eq. 1 and envision its physical backgrounds. Please write down, in words, why *m* and *h* are related to the second derivative of *z*, and why *c* is related to *z*. What is the physical meaning of *b*?

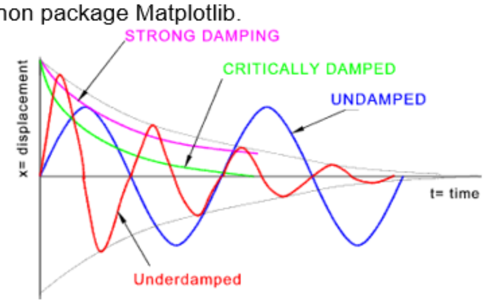
To solve eq. 2 analytically, we are looking for a function *z* = *z(t)* for which, apart from some constants, its second derivative equals its negation. More or less by coincidence we happen to know that this is the case for $z = \sin\,(\omega t + \;\alpha)$, where $\omega = \;\sqrt{c/(m+h)}$ and α is a constant known as the phase shift. For the first equation, with damping, also an analytical solution exist, however, that will not be presented here because it requires some deeper mathematical insight**. <u>Instead</u>**, we are aiming at a numerical solution. In the essence, the numerical solution solves eq. 1 with a sequence of small time steps Δt. Starting at t = 0 with an initial position and velocity of the cylinder, computing acceleration, velocity and position for the end of this time step, transfer those to the beginning of time step t = Δt etc. etc. This can continue forever, however, because we are only interested in the solution in a finite amount of time, it should stop at a practical moment.

The second task is to write a Python program for this purpose, and to test this with these parameters:

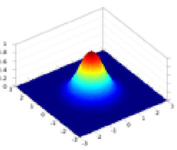
Cylinder draft	= 5 meter.
Cylinder cross section	= Circular, with a diameter of 1 meter.
Added mass h	= One third of cylinder solid mass.
Damping coefficient b	= One tenth of critical damping.
z at *t* = 0	= 1 meter.
Velocity at *t* = 0	= 0 (so, the cylinder is lifted one meter, and released without initial velocity).
Δ*t*	= 0.1 sec.
Total time	= Some three full periods.

Tabular output of this program does suffice, however it would enhance your work if some form of graphical depiction would be included as well, e.g. with Python package Matplotlib.

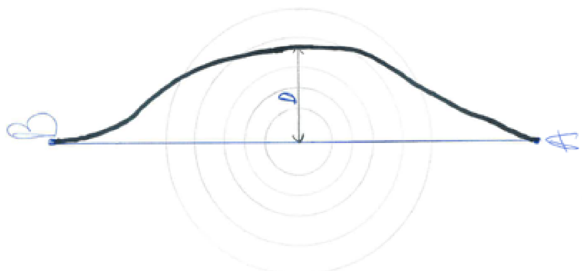
The so-called critical damping, as referred to, is exactly that damping factor which makes a mass-string system to perform half an oscillation before coming to standstill. This is depicted in the figure at the right, while the equation for this factor van be found in text books or on internet, e.g. en.wikipedia.org/wiki/Damping_ratio#Definition

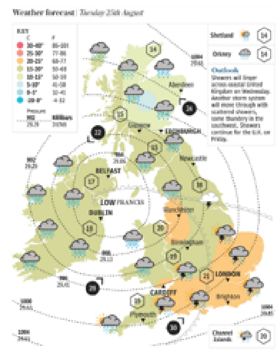


NO5 Weather routing A



A ship is sailing from A to B, a distance of 3000 nm. Right in between, summer storm Francis Is developing, with wind gusts to 70mph. Wind and waves in this storm lead to speed reduction, which is modelled by a symmetrical two-dimensional Gaussian function, see https://en.wikipedia.org/wiki/Gaussian_function#Two-dimensional_Gaussian_function, as depicted at the left, with standard deviation $\sigma_x = \sigma_y$ = 1000nm. The ship has a design speed of 16 knots, while the maximum speed reduction in the middle of the storm, parameter A of the Gaussian function, is 10 knots.





1. The master of the ship is inclined to smooth manoeuvres, so she chooses a cosine-like (in the interval 0 to 2π) trajectory shape, with a maximum distance D from the undisturbed trajectory. According to the sketch left. Please determine D which leads to the quickest passage through the storm.
2. This computational model is rather simplified. Please reconsider the whole aspect of ship routing, and conceptualize a more realistic model.