Hydrography education in Geodesy courses – case study in Maritime University of Szczecin

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SUMMARY

Hydrography and geodesy are both involved in earth surveying, although in various environments. It is however not obvious whether the hydrographers should be taught similar to land surveyors? Is a hydrographer some kind of special case of land surveyor? Or maybe teaching process should be more related to navigation and even marine environmental science? In this paper we address all these issues presenting the use case in Maritime University of Szczecin (MUS). Hydrographers have been taught there in Faculty of Navigation for more than 20 years already in various courses. The paper presents first the analysis of semantical and practical meaning and relationships between hydrography, geodesy, offshore surveying, remote sensing, cartography and geophysics. Then the analysis of IHO (International Hydrographic Organization) and IMO (International Maritime Organization) requirements for hydrography education are provided followed by polish implementation of them. The review of hydrographer's courses in Europe is given as well. Various approaches to this task on different levels are presented, based on courses' programs. Finally the use case itself is described, showing briefly the history of hydrography education in MUS and describing current implementation with relationship to IHO standards and other requirements. The equipment base including ships, measurement equipment and software are presented, together with staff experience. Finally the discussion is included commenting the results of former analysis and showing strengths and challenges of the approach in use case. Generalized conclusions are given to sum up the paper. They show that there are various possibilities of implementing requirements into course. They also show that there are overlapping competencies and knowledge between land and underwater surveying and that combining hydrography and geodesy in one course is reasonable and results in modern and high competence profile of graduates.

1. HYDROGRAPHY AND GEODESY

The relationship between geodesy and hydrography is ambiguous as the views on these terms and their definitions have been changed over time and within organizations.
IAG's (International Association of Geodesy) simple and generic definition says that "*Geodesy is the science concerned with the study of the shape, size and gravity field of the Earth*" (IAG, 2022). The definition itself focuses on big view of earth, geodynamics and gravity fields,

however the activities relates also to engineering measurements positioning and applications are also included in scope of organization. Similar approach can be met in NOAA (US National Oceanic and Atmospheric Administration), which defines geodes as "*the science of accurately measuring and understanding the Earth's geometric shape, orientation in space, and gravity field*" (NOAA, 2022a), focusing mostly on reference frames and satellite measurement techniques.

Hydrography according to IHO (International Hydrographic Association) is defined as "*the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defence, scientific research, and environmental protection*" (IHO, 2022). According to NOAA hydrography is "*the science that measures and describes the physical features of the navigable portion of the Earth's surface and adjoining coastal areas*" (NOAA, 2022b).

Analyzing above definitions we can find some common issues between geodesy and hydrography. They have both scientific background and they are both involved in measuring earth-related features. However geodesy is focused more on understanding Earth as a whole and on establishing usable reference frames, while hydrography more on description of water bodies for their future use.

Taking into account the scope of this paper, which is education of hydrography, it is reasonable to analyze also more utilitarian aspects of both. It first academic level (B.Sc) the main effort is usually laid on teaching surveying techniques, which are necessary to perform measurements in land as well as in water environment.

NOAA has separate definition for land surveying, which is understood as "*the science of measuring land to determine points on the ground and the angles, distances and heights between them*". These definition can be easily extended to "*the technique and science of accurately determining the terrestrial or three-dimensional space position of points and the distances and angles between them*" (SAM, 2022), which is not restricted solely to land areas. These leads directly to the role and definition of the surveyor provided by FIG, which is broadly known. According to this, a surveyor is "*a person with the academic qualifications and technical expertise to conduct one, or more, of the following activities;*

- *to determine, measure and represent land, three-dimensional objects, point-fields and trajectories;*
- *to assemble and interpret land and geographically related information,*
- *to use that information for the planning and efficient administration of the land, the sea and any structures thereon; and,*
- *to conduct research into the above practices and to develop them" (https://www.fig.net/about/general/definition/definition.pdf).*

Summing up it can be said that hydrographic surveying can be treated as a kind of specialized geodetic surveying. Hydrography use the frames and partially terms established by geodesy. Despite different scopes of both, many common issues can be found especially related to measurements and charting. Therefore, it seems that hydrographic education can be treated as a specialized case of subject of Geodesy. The deliberation in this paper, as well as the degree program in Maritime University of Szczecin are prepared in line with this thesis.

2. IMO REQUIREMENTS FOR TRAINING OF HYDROGRAPHIC SURVEYORS

International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and air pollution by ships. Due to marine safety, IMO establishes many rules and requirements covering, among others, cargo and containers security including dangerous goods shipping and fire protection, safety of navigation systems such AIS (Automatic Identification Systems), ENC (Electronic Navigational Charts) and ECDIS (Electronic Chart Display and Information Systems) and radiocommunications and search and rescue procedures. Within the scope of safety navigation one can find the regulations about hydrographic data, nautical charts and publications. Due to International Convention for the Safety of Life at Sea (SOLAS) regulations chapter V, all vessels are required to carry up-to-date charts but originally SOLAS did not specify govermental responsibility for chart production. In 1983 IMO undertook the resolution relating the importance of the provision of accurate and up-to-date hydrographic information, such depths, underwater obstacles and others which may have an impact for safety navigation. This IMO resolution invited governments to carry out hydrographic surveys on the areas that are under their management and also to cooperate with other governments in case of borader waters. In 1985 IMO presented the resolution which were urging IMO members governments to appoint regional hydrographic commissions or groups that are responsible for nautical charts. IMO does not make any requirements due to hydrographic surveyors trainning processes or getting diploma, only calls on the members to conduct hydrographic surveying in the most modern and accurate way and to keep nautical charts and other aids to navigation up-to-date. In July 2002, the revised Chapter V of the IMO Safety of Life at Sea (SOLAS) Convention entered into force. Under the new Regulation 9, the Contracting Governments of SOLAS are now required to provide and maintain Hydrographic Services and products. Vast improvement in shipping industry caused that Many charts which were adequate a decade ago, may have to be recompiled using new survey data, collected to a higher degree of accuracy and providing improved coverage.
IMO adrreses all theses concerns however it does not directly set up the requirements for hydrographic products as these technological details are not whithin the scope of this Organization.

3. IHO REQUIREMENTS FOR TRAINING OF HYDROGRAPHIC SURVEYORS

Education and training of hydrographic surveyors is treated in IHO as one of the key issues as it is placed in front of the Capacity Building Programme. IHO, together with FIG and ICA

(International Cartographic Association) have established International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC). The board reviews syllabi of programmes and individual recognition schemes from education and training institutions. However the requirements for training programs for hydrographic surveyors and their categories are elaborated solely by IHO itself.

Theoretical and practical scope related to the training of both A and B category hydrographers is strictly defined by the *S-5 Standards of Competence for Category "A" (or "B") of Hydrographic Surveyors International Hydrographic Organization* (IHO, 2018). Current version is 1.0.2 of June 2018 for "A" category and 1.0.1 from June 2017 for "B" category. Both standards were developed in collaboration with International Federation for Surveyors (FIG*)* and International Cartographic Association (ICA). Both standards indicate minimum theoretical and practical competences.
The intention to separate the standards into "A" and "B" is that a person with category "A" qualification, having appropriate experience, can work as a specialist in government, industrial or academic institutions. They are also able to supervise and approve the hydrographic measurements. On the other hand, the one with "B" category, having theoretical knowledge extended by experience, is a person who is specializing in providing products and services in accordance with the required specifications, and whose work is supervised and approved by "A" category hydrographer.
Thematic cross-section for both standards is different. The description of the topics and competences, which a hydrographer should have is given starting with "B" category. The standard is divided into two modules, containing the so-called ***B****asic* and ***E****ssential Subjects*. First thematic set includes, among others:

- *B1. Mathematics, Statistics, Theory of Errors:* including linear algebra, differential calculus, trigonometry, statistics such variance, mean, correlation, standard deviation, normal distribution.
- *B2. Information and Communication Technology*: including computer systems, office software, programming: algorithms, basic scripting, data exchanging and file conversions, web and network communications and databases.
- *B3. Physics*: including mechanics with kinematics, Coriolis effect and Newton`s law, gravity and waves theory with propagation, radiation, emission, absorption, reflection, refraction and electromagnetic spectrum.
- *B4. Earth Sciences*: including geography and geology topics.
- *B5. Nautical Science*: including aids to navigation, GMDSS system, nautical charts and publications, emergency procedures, towing sensors procedure, anchoring and instrument moorings.
- *B6. Meteorology*: including weather and wind observation and weather forecasting.

Essential subjects include:

- *E1. Underwater Acoustics*: consists of acoustic waves theory with propagation, sound speed, sonar equation, transducer principles and beam characteristics and system`s parameters such bandwidth, pulse length, gain, detection threshold, absorption, range and spatial resolution. It is also divided into subtopics such: single beam systems and side scan sonar and swath systems, where systems operations and working procedures for that systems are included.
- *E2. Remote Sensing*: consists of airborne and terrestrial LiDAR systems and products; other remote sensing systems for bathymetry measurements and shoreline delineation.
- *E3. Water Levels and Flow*: consists of tidal and currents fundamentals, water level and tidal measurements, water levels datums and water level reductions of soundings.
- *E4. Positioning*: including geodesy, principles of cartography, positioning methods and techniques, vertical and acoustic positioning, fundamentals of inertial navigation and of course knowledge of sources of uncertainty.
- *E5. Hydrographic Practice*: including hydrographic survey planning documentations preparing, hydrographic survey operations and survey documentation with final products.
- *E6. Hydrographic Data Management*: with data acquisition, real-time data monitoring, data storage and transferring, processing and analysis of the data, data organization and visualization.
- *E7. Environment*: physical properties of sea water, oceanographic measurements such: temperature, conductivity, salinity and other need for systems calibration; marine geology and geophysics with seabed characteristics, magnetic and seismic surveying and at least impact of hydrographic survey.

Thematic scope for training of an "A" hydrographers is more extensive. It does contain modules from ***B**asic Subjects* and other topics are included in the ***F**oundations Science* subjects and ***H**ydrographic Science* subjects modules. And so accordingly:

- *F1. Earth Models*: including the physical geodesy such gravity field of Earth and gravity observations, height determination and height systems, geopotential and geoidal modelling; coordinate systems, land surveying techniques and methods, levelling and map projections.
- *F2. Oceanography*: consists of sea waves theory, oceanographic measurements and water masses circulation.
- *F3. Geology and Geophysics* with magnetic and gravity Earth fields, gravity and magnetic prospections, measurements and models and seismic surveying.

- *H1. Positioning* with topics of vessel and sensors references, GNSS positioning theory and measurements, system installation, operation and quality control, inertial navigation systems, underwater acoustic positioning systems, line keeping.
- *H2. Underwater sensors and data Processing*: including propagation of acoustic waves and noise, single beam, sonar systems and swath systems, their usage, limitations, calibrations and quality control.

- *H3. LiDAR and Remote Sensing* with airborne LiDAR systems components and usage and other remote sensing sensors and systems.
- *H4. Survey Operations and Applications* which consists of subjects about hydrographic survey projects with survey requirements and project management, hydrographic survey operations with planning, survey operations including bathymetric, sonar, magnetometer, LiDAR systems; seabed characterizations with classification from acoustic and optical data and seabed sampling.
- *H5. Water Levels and Flow* with water level principles, tidal and current measurements and datums.
- *H6. Hydrographic Data Acquisitions and Processing* including data acquisition principles, real-time monitoring, filtering of the data, processing and corrections; spatial data quality control and interpolation.
- *H7. Management of Hydrographic Data* with subjects about databases and marine GIS.
- *H8. Legal Aspects* when you one should get the knowledge about hydrographic product liability and responsibilities of the hydrographic surveyor and specification of maritime zones.

Both programmes, for “A” and “B” category, must include a supervised and evaluated *Field Project*. For a "B” category *The Comprehensive Final Field Project* (CFFP) of hydrographic surveying programme exercises the skills of the students to carry out various hydrographic surveying tasks, from planning, calibration, data acquisition and then processing and analysing the data, for final products preparations, reporting and data managing. For students of a S-5 category "A" programme, a *Complex Multidisciplinary Field Project* (CMFP) is required. It includes also analytical reasoning, decision making and development of solutions to non-routine problems. Both field projects: CFFP and CMFP subjects and range of practical exercises can be found in *Guidelines for the Implementation of the Standards of Competence for Hydrographic Surveyors and Nautical Cartographers* (IHO, 2017). This guidelines are available from IHO website and the last valid version is 2.0.0 from March 2017.

After completing the theoretical course and relevant field project, potential hydrographer must undergo certified apprenticeship to get the diploma. For diploma “A” 450 days are assumed, and one day of practice is considered to be 8 hours of work related to hydrographic measurements. For “B” category it is assumed to be 225 days.

4. HYDRPOGRAPHY EDUCATION WORLDWIDE

There are several education centres in the world, which are providing hydrographic courses recognized by IHO/FIG/ICA. This included both ”A” and ”B” category courses, however ”B” courses are more common, as they are available in 34 places. ”A” category courses are availale only in 20 centres worldwide (fig.1), most of them in Europe (41%) and Asia (29%). In North and South America, 12% and 18% of courses are respectively present. There are countries like France, Malayisa and USA in which two independent centres provide A category courses. There are no ”A” category recognized courses in Australia or in Africa.

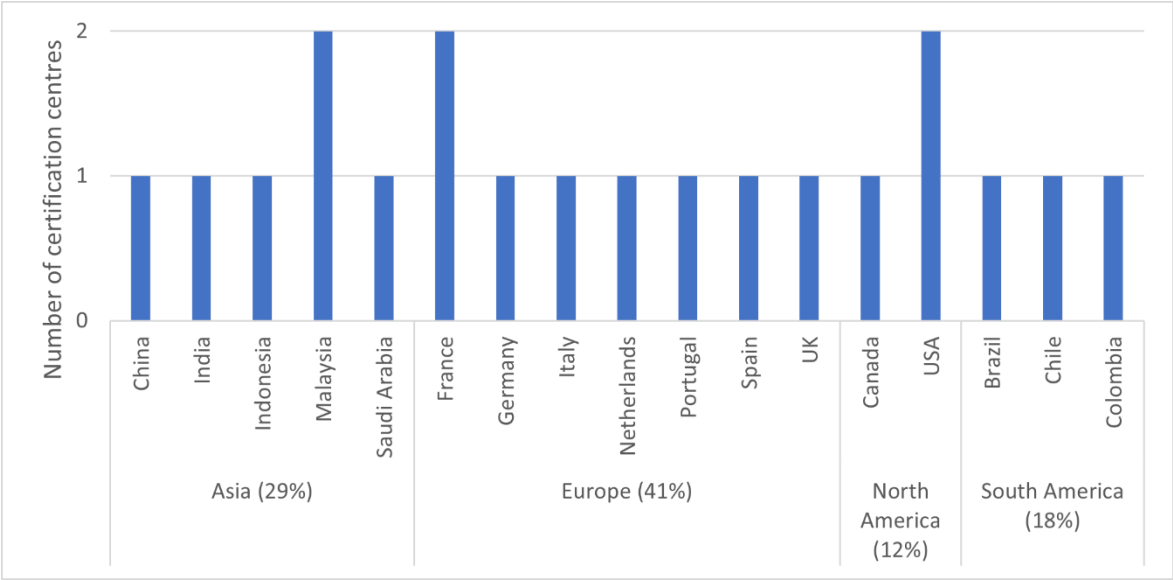

Fig. 1. Numbers of certification centers with A recognized hydrography programmes.

The analysis is a bit different in case of ”B” category recognized courses (fig. 2 and fig. 3). First of, all the courses are available in all inhabilted continents. Most of them is in Asia (39%) and in Europe (29%). North and South America are in similiar level as in ”B” category courses – 7% and 18% respectively. Additionaly Africa (Egypt in fact) and Australia appears having 4% in this level as well. Again, there are some countries with two centres providing ”B” category courses – UK, Canada, USA, India, Japa and Turkey. Only USA has two centres with ”A” and ”B” category courses.

In most cases places providing ”A” category courses, provides also ”B” category courses, except of Germany and Chile which has only ”A” category course.

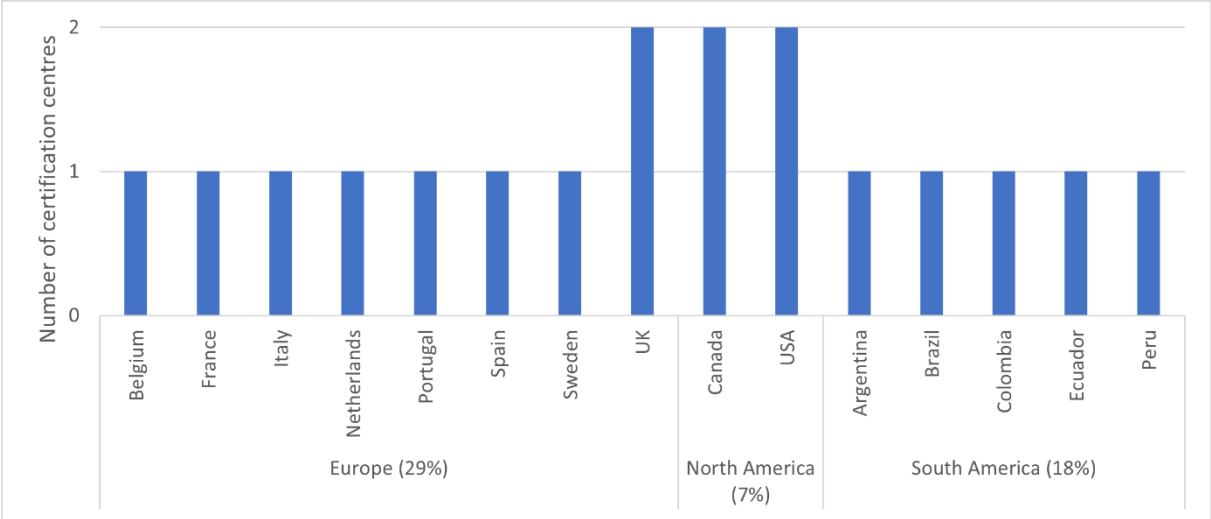

Fig. 2. Numbers of certification centers with B recognized hydrography programmes (part 1)

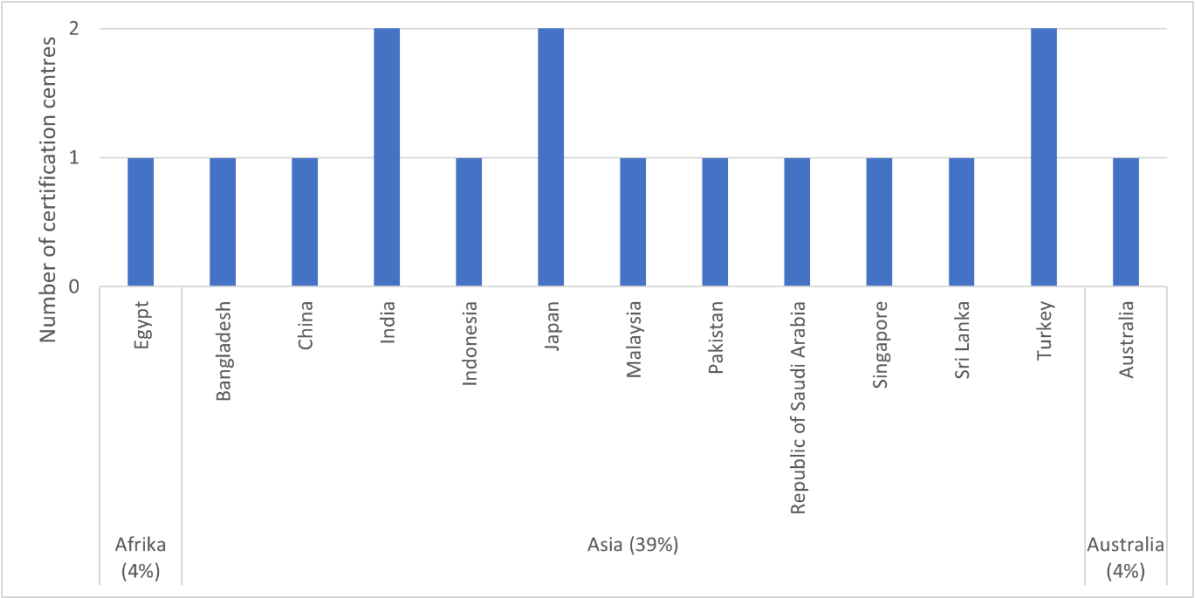

Fig. 3. Numbers of certification centers with B recognized hydrography programmes (part 2)

The analysis shows that education in Hydrography takes place worldwide in "B"-category level, however in case of "A" category Australia and Africa do not have appropriate courses. Europe has a strong representation in the society, leading the number of facilities providing "A" category courses and being in 2nd place in "B" category level. Nine nations in Europe provide recognized hydrography education. There are also some other countries, like Poland which provide education on appropriate level, however without having recognition certificate.

5. POLISH APPROACH TO IHO REGULATIONS

Poland's representative in IHO and its committees and groups is the Hydrographic Office of the Polish Navy (HOPN). It is a part of the service which is subordinate to the Polish Navy and the Minister of National Defense. Other duties include navigational, hydrographic, oceanographic and meteorological tasks for the Navy, analysis and verification of hydrographic measurements in Polish maritime areas, preparation of nautical charts and publications, and maintaining a national system for the circulation of nautical information and navigational warnings.
Certificates of A and B categories are required to carry out a hydrographic survey in Polish maritime areas for any hydro-engineering projects and especially for securing the safety of navigation. In Poland, the supervision of the granting of authorizations according to the *Regulation of the Minister of National Defense dated 17 September 2018 on qualification requirements for hydrographic surveying* is assigned to the Head of the Hydrographic Office of the Navy. In accordance with it, performing of hydrographic measurements in Polish sea areas for the purposes of navigation safety, maritime cartography, designing the foundation and control of hydrotechnical structures, spatial planning and environmental protection requires:

- **category B** – theoretical knowledge and practical skills that allow for independent:
    - preparation of the equipment necessary for measurements carried out as part of hydrographic works,
    - performing measurements with the use of various systems and measuring devices, taking into account the errors and limitations of the devices used,
    - carrying out current control of measurements and preliminary processing of their results.
- **category A** – theoretical knowledge and practical skills that allow you to independently:
    - planning, conducting and supervising comprehensive hydrographic works,
    - performing quality control of hydrographic works,
    - authorizing the performed hydrographic works,
    - performing other tasks of hydrographic protection of human activities at sea.

The prospective certified hydrographer must present documents to the Chief of the BHMW showing completion of a study profile or course containing a defined scope of subjects and documented hydrographic practice under the supervision of a Category A hydrographer.

The second mission of the Chief of the HOPN is to certify institutions, organizations, and training centers for meeting criteria equivalent to the training topics for Category A and B hydrographers. Before granting permission to conduct training, the institution submits the necessary documentation to certify the didactic and formal preparation. HOPN can grant the Institution with the certificate of compliance with "A" or "B" category education requirements.

6. HYDROGRAPHY EDUCATION IN MARITIME UNIVERSITY OF SZCZECIN

Navigation has been one of classical, traditional degree courses in Maritime University of Szczecin since its founding. STCW (IMO Standards for Training Certification and Watchkeeping) requirements was the basis for teaching Navigation and a key competence of faulty staff. In the end of 20th century new challenges have appeared and new specialties were introduced within the programme. One of them was Hydrographic Survey and Navigational Aids. The tradition of extensive teaching of hydrography in Maritime University in Szczecin has thus more than 20 years.

The specialty Hydrographic Survey and Navigational Aids was provided within the degree course of Navigation. Therefore students had full STCW compliant course for officer in charge of navigational watch and additionally classes about hydrography, surveying, navigational aids and nautical charts production. Practical classes were carried out with the use of research school ship Nawigator XXI and with the equipment and in cooperation with Maritime Office in Szczecin, which is responsible for hydrographic works in Szczecin-Świnoujście fairway. Thus theoretical classes were supplemented with practice. Graduates were fully educated navigational officers with additional knowledge of hydrography. STCW program requirements was simultaneously advantage and disadvantage in this situation. On one hand graduates could work both as navigators and as hydrographers. On the other hand STCW courses were taking

so much time that hydrographical issues had to be limited in the program. Especially issues with shore and offshore surveys were not included.
In 2008 a new degree course of Geodesy and Cartography was opened in Maritime University of Szczecin in the Faculty of Navigation. According to law requirements some part of subjects were to be selected by students. It was decided to create a set of hydrographical classes as a topical module within these selectable subjects, in the amount of 30% of them. Thus hydrography education was established in the degree course of Geodesy and Cartography. Students were thought basic hydrographical issues on top of geodetic and cartographic knowledge. This combination allowed graduates to become universal land and hydrographic surveyors. New hydrographic boat for research and teaching purposes was bought – HYDROGRAF XXI, together with interferometric echosounder, single beam, sonar, RTK and satellite heading system. Thus students were able to practice on a small boat as well as on the research ship. However, although hydrographic issues were thought, no official specialty was established. This situation has changed in 2018, when the situation was formalized and official specialty of Hydrography was established within degree course of Geodesy and Cartography. Equipment was satisfactory and faculty staff was experienced enough to provide fully educated hydrographers to the market. Many of them have already "A" category certificates and they have been working in the world-wide hydrography and offshore business.
In 2019 the efforts were started to receive certificate for the teaching program from HOPN. The set of changes was agreed according to IHO S-5 requirements. It meant mostly reorganization of the program, however additional classes were also introduced. During the works it was noticed that most of the required content was already included however it was grouped in other way. Therefore program was adjusted to clearly fulfill the requirements. Also the field project was reorganized. As a result the certificate from HOPN was received that the program fulfills requirements for teaching at "A" category level. This certificate may be the basis for HOPN, while issuing certificates for graduates (after fulfilling practical requirements).
The next step in future would be applying for recognition of the program by IBSC, however this would probably require also some institutional changes.

7. MODIFICATION OF TEACHING PROGRAMME TOWARDS CERTIFICATION

The teaching programme for Hydrography specialty within undergraduate (1st cycle) degree course of Geodesy and Cartogreaphy has been revised to meet the requirements of international Standards of Competence for Category "A" Hydrographic Surveyors S-5A (IHO, 2018). This chapter describes the alignment of the teaching programme to the S-5A standard with the three categories within it: basic subjects, foundation science subjects and hydrographic science subjects.

Basic subjects

The basics subjects are divided into the following main groups:

1) B1: Mathematics, statistics, theory of observations,

2) B2: Information and Communication Technology,
3) B3: Physics,
4) B4: Nautical science,
5) B5: Meteorology, and each of these has specific topics listed.

Part B1 is included in the teaching programme in the *Mathematics* course, which is delivered in semesters 1 and 2. All specific topics i.e. geometry and linear algebra (B1.1), differential calculus and differential equations (B1.2) and probability and statistics (B1.3) are discussed during these classes.

Part B2 is divided into five main groups. The first three i.e., computer systems (B2.1), office work software suites (B2.2) and programming (B2.3) are included in the programme in the *Information Technology* course, which is implemented in semester 1. Part of course B2.3 (programming) has been introduced together with B2.5 (databases) in the *Geodetic and Cartographic Informatics* course, which is delivered in semesters 2 and 3. In addition, topic B2.4 (web and network services) is in the *Data Communications Systems* course in semester 6.

The whole of section B3 (which includes the topics: kinematics, gravity, magnetism, waves, electromagnetic waves, geometrical optics, lasers, transducers, and clocks) is implemented in the *Physics* course in semesters 1 and 2.

Most of the subjects in Unit B4 have been included in the *Nautica* course taken in semester 5. These group of subject include:

- B4.1: Conventional aids to navigation,
- B4.2: GMDSS,
- B4.3: Nautical Charts,
- B4.4: Navigation Publications,
- B4.5: Compasses,
- B4.6: Emergency Procedures,
- B4.7: Safe working practice,
- B4.8: Rope and Wires,
- B4.10: Anchoring,
- B4.11: Instrument moorings.

Only part B4.9 (towed and over the side) instruments has been entered in the *Hydrographic Equipment and Measurement Systems* course, which is taken in semester 5.

The entire section of B5, which includes weather fundamentals and observations (B5.1), wind, waves and seas (B5.2) and weather forecasting (B5.3) is covered in the *Meteorology and Oceanography* course in semesters 2 and 3.

Foundation science subjects

The subjects in this section fall into three main groups:

1) F1: Earth Models,
2) F2: Oceanography,
3) F3: Geology and geophysics,

The F1 is divided into six main sub-groups. Subjects related to F1.1 (physical geodesy) and F1.2 (coordinate systems) are taken in *Higher Geodesy and Geodynamics* course, which are in semesters 3 and 4. Land surveying methods and techniques (F1.3) and levelling (F1.4) are taken

in two different subjects: the *Fundamentals of Surveying* course (semester 1) and the *Surveying Measurement Technology* course (semesters 2 and 3). All topics related to map projections (F1.5) are covered in the *Mathematical Foundations of Cartography* course (semester 3). The F1.6 (trigonometry and least-squares) is implemented during three subjects:

- F1.6a: Trigonometry – the *Mathematics* course (semesters 1 and 2),
- F1.6b: Theory of observations – the *Survey Adjustment* course (semesters 3 and 4),
- F1.6c Least squares – the *Satellite Geodesy* course (semesters 4 and 5) and *Survey Adjustment* course (semesters 3 and 4).

The entire F2 section (oceanography) is implemented in the *Meteorology and Oceanography* course in semesters 2 and 3. However, all topics in section F3: geology and geophysics are included in the *Fundamentals of Geology and Geophysics* course in semester 2.

Hydrographic science subjects

The final module of hydrography-related subjects is divided into the following groups:

1) H1: Positioning,
1) H2: Underwater Sensors and Data Processing,
2) H3: LiDAR and Remote Sensing,
3) H4: Survey Operations and Applications,
4) H5: Water Levels and Flow,
5) H6: Hydrographic Data Acquisition and Processing,
6) H7: Management of Hydrographic Data,
7) H8: Legal Aspects.

In the first group we have vessel and sensor reference frames (H1.1) and GNSS positioning (H1.2), some of whose topics are included in the *Hydrographic Equipment and Measurement Systems* course (semester 5). In addition, topics related to H1.1a (common reference frames for sensors) and H1.1b (integration of reference frames) are included in the programme in the *Engineering Geodesy* course (semesters 4, 5 and 6). On the other hand, topics from sections H1.2 (GNSS signals, GNSS observables, relative and absolute techniques, installation and operation, quality control) are included in the course syllabus for the *Satellite Geodesy* (semesters 4 and 5). All topics from sections H1.3: inertial navigation systems, H1.4: subsea positioning and H1.5: line keeping are included in the course called the *Integrated Hydrographic Systems* (semester 7).

The topics from modules H2.1: underwater acoustics, H2.2: single beam systems, H2.3: sonar imagery systems, H2.4: swath echo sounder systems and H2.5: backscatter are covered in the Hydrographic *Equipment and Measurement Systems* course (semester 5). Some of the specific topics from H2.4 are also included in the *Hydrographic Surveying* course programme delivered in semester 6.

The H.3 module is included in the programmes of three courses: the *Laser Scanning* (semesters 5 and 6), the *Photogrammetry* (semesters 4 and 5) and the *Remote Sensing* (semester 5).

The topics form H.4 module divided on three main groups:

- H4.1: Hydrographic survey projects,
- H4.2: Hydrographic survey operations,
- H4.3: Seabed characterization.

The topics in this section are covered in the following courses:

- the *Hydrographic Surveying* course (semester 6) – H4.1a: hydrographic survey requirements; H4.1b: hydrographic survey project management; H4.2a: survey planning; H4.2d magnetic surveys; H4.3c: seabed sampling; H4.3d: seabed characterization.
- the *Hydrographic Equipment and Measurement Systems* course (semester 5) – H4.2b single beam operations; H4.2c multibeam and interferometric operations; H4.2f side scan sonar operations; H4.2g side-scan sonar data interpretation.
- the *Laser Scanning* course (semesters 5 and 6) – H4.2e: airborne LiDAR surveys.
- the *Hydrographic Data Analysis* course (semester 6) – H4.3a classification from acoustic data; H4.3b classification from optical data.

The H.5 module is included in the programmes of two courses: the *Nautica* course taken in semester 5 and the *Meteorology and Oceanography* course taken in semesters 2 and 3.
The H6: Hydrographic Data Acquisition and Processing module is also quite extensive in terms of subject matter. The subjects are covered in the following courses:

- the *Hydrographic Surveying* course (semester 6) – H6.1: real-time data acquisition and control; H6.2a: filtering and estimation of single beam data; H6.2b: filtering and estimation of multi-beam data; H6.2c: spatial data quality control.
- the *Hydrographic Data Analysis* course (semester 6) – H6.2d: spatial data interpolation.
- the *Marine Geoinformation Systems* course (semester 5) – H6.2e: spatial data representation.

The *Marine Geoinformation Systems* course also includes topics from the modules data organization and presentation (H7.1) and marine data sources and dissemination (H7.2). While the topics from module related to spatial data integration and deliverables (H7.3) have been allocated to several course programmes: the *Geodetic Application Programs* course (semester 6), the *Geodetic and Cartographic Informatics* course (semesters 2 and 3), the *Hydrographic Data Analysis* course (semester 6), the *Marine Geoinformation Systems* course (semester 5), the *Hydrographic Surveying* course (semester 6) and the *Electronic Navigational Chart* course (semester 7).
The last H.8 module is delivered on the following courses: the *Nautica* course (semester 5), the *Professional Ethics* course (semester 2) the *Selected Issues in Geodetic Law* course (semester 7), and the *Protection of the Natural Environment* course (semester 7).
Each of the topics from standard S-5A has been written into the latest teaching programme.

8. NEW TEACHING PROGRAMME SUMMARY

New teaching program for the undergraduate degree course of Geodesy and Cartography including specialty of Hydorgraphy was established in 2020. It covers all the requirements of IHO S-5 and it was certified by Polish HOPN. The idea is to educate professional surveyor, who can perform surveys both on water and at the sea side. Students get extensive knowledge about functioning and handling of geodetic and hydrographical measurement systems, as well as data processing. Simultanously, program covers also isseus of related to reference systems, Earth gravity, geodynamics, cartography as well as law issues. Students understand processes and information flow in typical geodetic and hydrographic works.

Altogether the program covers 2 605 teaching hours within 7 semesters (3,5 year). Graduates receives the degree of Bachelor of Science (Engineer) in Geodesy and Cartography with the specialty of Hydrography. 1 050 hours are lectures, while 1 300 hours are laboratories and exercises in which student learns how to solve practical problems and how to carry out practical tasks. On top of it there are 255 hours of projects in various courses focusing mostly on practical works. In this forms students have to provide solution of typical engineering problems based on gathered knowledge. The number of various forms of classes is well balanced, offering both theoretical knowledge and practical skills.

Two first years of studies is common for both specialties (hydrography and geoinformatics). Students get skills and knowledge in general subjects like language, IT, entrepreneurship, ethics, ecology and in basic subjects like mathematics, physics, engineering graphics, informatics and algorithmics. Some of degree subjects are also in this period to present basic directions and led students toward their choice of specialty. These are basics of geodesy, basics of hydrography, basics of navigation, cartography, basics of surveying, basics of geology and geophysics, survey adjustment.

Third and fourth year is a continuation of degree subjects and full set of specialty subjects. In the first group there are subjects like photogrammetry, teledetection, geodetic measurements, satellite geodesy, geoinformatics, engineering geodesy. Specialty subjects cover more than 500 hours, including 330 hours of laboratories and projects. These are subjects like hydrographic measurement systems and devices, nautica, maritime geoinformatics systems, electronic nautical charts, hydrographic works, hydrographic surveys, data transmission systems and integrated hydrographic systems. Hydrographical issues are also included in other subjects as it was indicated in previous section.

Field project which is required also in the program is implemented during project lessons in various subjects. The measurement part is covered during one-week stay on board of research ship Nawigator XXI and other surveys are gathered during projects on the boast Hydrograf XXI. Data processing is then performed during other projects. In such way each student performs a unique complex and multidisciplinary project during teaching process in which he/she is performing typical works of hydrographer starting from campaign planning through the surveying up to post-processing and final products preparation.

The studies are supplemented with internships in the geodetic and hydrographic companies. At the end final thesis is also required and the programme is finished with final exam.

The subjects are held with professional staff of the faculty including ”A” and ”B” category hydrographers, master mariners, geodesists and professors which gives extensive theoretical and practical experiences. Additionally to above mentioned equipment, specialized hydrographic and geoinformatics software is used.

Proposed degree course is a complex and multidisciplinary approach to educate universal hydrographic surveyor, who is able not only to maintain hydrographic surveys, but also to perform land surveys and understand basic navigational constraints.

9. DISCUSSION AND CONCLUSIONS

Teaching hydrography is an important task of education systems nowadays. In the era of growing shipping industry (more and larger ships) and increasing maritime transportation,

accurate and up-to-date navigational charts are vital requirement. Additionally these are the times of green energy boom causing growing offshore industry to develop even faster, urging needs for hydrographers in the market. Taking these into account it can be even said that hydrography education becomes a necessity for any sea related nation.
We have been teaching hydrography for more than 20 years already in Maritime University of Szczecin and during this time we have tested various models and methods for this education. There have been courses in the rank of specialty in Navigation subject, but also in the rank of modules in Geodesy and Cartography subject. Finally we have established specialty of Hydrography in the subject of Geodesy and Cartography. We have also adjusted the program to fulfil IHO S-5 requirements, for which we have been granted a certificate by Hydrographic Office of the Polish Navy, which is polish member in IHO.
Each of the models have its advantages and disadvantages. Hydrography courses have to be adopted somehow into wider program if it is to be at academic level to fulfil other educational requirements. Using Navigation according STCW as a basis for this causes that student understands entire flow of working at sea. On the other hand STCW program is demanding and there is not much time for hydrographic courses. Therefore we have finally decided to use Geodesy and Cartography as a base. Many IHO requirements are reflected in geodesy subjects and as so there is more time for teaching specialized hydrographic issues in dedicated courses. At the moment we have introduced all ”A” category requirements into 1st academic cycle studies (undergraduate, B.Sc./Engineer). We plan however enlarge the portfolio in future with 2nd cycle (graduate, M.Sc.) heading probably towards offshore survey.

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BIOGRAPHICAL NOTES

All authors are members of Chair of Geoinformatics and Hydrography in the Faculty of Navigation in Maritime University of Szczecin. They have all been involved in setting up hydrographic courses and programs in MUS. I. Bodus-Olkowska and G. Zaniewicz are “A” category hydrographers. M. Włodarczyk-Sielicka is an assistant professor in MSU and hold “B” category hydrographer. W. Kazimierski and J.Łubczonek are associate professors in MUS with navigational experience at sea. W. Kazimierski additionally used to work as online surveyor on offshore vessels.

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