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On navigation as a scientific discipline

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Abstract

The author continues considerations aimed at justifying the establishment of navigation as a scientific discipline, which began in his article included in the collective work titled *Admiralski farwater* (Walczak, 2015b) (*Admiral's Fairway*), and presents the subject and scope of navigation and sets forth other arguments supporting the idea. The author provides further arguments for the draft classification in which navigation would be an independent discipline of technical sciences, indicating the transdisciplinary nature of navigation within a framework of strict relationships with other domains of science in various fields of knowledge.

Science is a vast arena, encompassing a multitude of different areas, fields and disciplines. It comprises research proper as well as educational activities aimed at imparting knowledge and skills.

The classification of science dates back to the times of Plato, Aristotle, then Descartes and, in the 19th century, Comte. Today various systems divide objects of cognition into classes, families, etc. according to selected criteria.

Historically, the divisions varied depending on the assumed criteria. These in turn were determined by the knowledge and social development of the time. The classification was a process that evolved from cognitive purposes in ancient times to more the familiar classification of science by Comte, who introduced objective criteria derived from the positivist mainstream, dividing sciences according to the degree of abstraction, generality and simplicity.

The basic division by the degree of abstraction distinguished fundamental and concrete sciences. The former included the sciences of laws and processes ordered by the decreasing degree of generality and simplicity: mathematics, astronomy, physics, chemistry, biology, sociology. The concrete sciences addressed specific groups of facts and things: microbiology, zoology, botany, medicine, etc. None of those sciences, however, was formed completely at that time. Being formed from a basis of abstract sciences, concrete sciences were referred to as derivative sciences (Such, 1973, pp. 37–41).

It is not my goal to present the development of sciences across centuries or decades and their historical classifications, but to draw readers' attention to contemporary development trends in the light of the dynamic progress of civilization. This phenomenon, in terms of information technology, globalization of industry and trade, particularly in science, is unprecedented in the history of humankind. One proof of that is the statistics of knowledge resources growth: over the past six years, more research results have been collected than throughout the history of past ages (Fazlagić, 2002, p. 33).

Looking at the present list of areas of knowledge, fields of science and arts, and scientific and art disciplines, we can identify new fields and disciplines of science, illustrating the need for an interdisciplinary approach (biophysics, biotechnology, biocybernetics, biomedical engineering, etc.). This diversity has motivated the author to address the topic (Walczak, 2015a, p. 41).

Research and technological progress have also affected the maritime domain. The subject of navigation has its history and tradition, aptly expressed

by the ancient Roman saying '*Navigare neccesse est, vivere non est necesse*' that has been oft quoted since it was coined.

Previously it had a specific sense in sailing, where ships were propelled by the power of human muscles (oars) or by wind. The saying remains valid in modern civilization, as knowledge of navigation is a prerequisite for safe movement of vehicles. The importance of navigation has increased in scope of practical applications and expanded its area of scientific research, going beyond sea and inland water areas. Navigation is in use on land (road vehicles), in the air (passenger planes, military aircraft, balloons, drones) and in space (space vehicles and stationary bases).

Back onto the chronological track – let us bear in mind that navigation has been practised at sea since the origin of humankind. Movement of sailing vessels was based at night on observations of the pole star, and its position relative to the moving vessel, and in daytime on observations of the sun. The above method was later improved thanks to scientific data and findings of astronomers, then was connected with published tables and nautical almanacs, listing the variable parameters of the sun, the moon, stars and planets, time of their rising and setting and other data the navigator needs to determine a ship's position (Grajewski & Wójcicki, 1981, p. 15). Thus the integrated knowledge of celestial navigation was established.

We can similarly present the later concepts of radionavigation, radiolocation, the dissemination of that knowledge in maritime navigation and aviation, using radio and meteorological systems to guide vessels' conduct through areas of favourable weather, or the implementation of satellite systems: GPS, DGPS, GLONASS and the latest, GALILEO.

Land navigation also makes use of these systems for land transport vehicle positioning and passage time estimation from electronic calculations.

In this context, we should also mention information from a Voyage Data Recorder, Vessel Traffic Services System, Automatic Identification System and, first and foremost, the integrated Electronic Chart Display and Information System. In aviation, integrated displays are of particular importance, as they enable the pilot to promptly assess the present situation and facilitate decision making (displays of VST – vertical situation, HST – horizontal situation).

Navigational equipment and systems are also used in space, controlling the movement of vehicles outside the earth's atmosphere.

In my understanding, the image of contemporary civilization cannot be fully perceived without noting the development of sciences, research directions and the strict interrelations of various fields and disciplines. This refers to the integration of fundamental sciences with practical ones, as well as the interdisciplinary nature of scientific knowledge: the use of discoveries in one field or discipline in other disciplines.

As for the problems of marine navigation – the area that I am most familiar with – it seems necessary to me to analyse the current relationships of the safety of *navigation* with *transport* and *geodesy and cartography*. Is this the right approach?

The basic relationship of navigation with geodesy and cartography derives from similar methods of position determination, although in practice differences are significant, as navigators determine positions of moving objects, not stationary. The relationship of navigation with transport looks more solid. Both disciplines have some things in common: choice and optimization of the route, positioning, and the carriage of cargo – although environments and cargo sizes differ. These do not apply to pipeline and rail transport, as both have nothing to do with navigation.

Medical sciences had similar classification difficulties, since medicine, like navigation, for centuries was treated not as science but art, with no causal relations to science. To date, many countries (e.g. Great Britain) still exclude medicine from science classifications, and research results utilized to promote the development of medicine are provided by fundamental, natural, technical sciences and the humanities.

The Polish classification of academic disciplines and fields, where medicine is regarded as a science, distinguishes the areas of medical science, health science and sport science (Rozporządzenie, 2011).

Overall progress of civilization, with the need to employ the knowledge of other fields and disciplines for better methods of solving complex health problems has led to changes in the classification of sciences, confirming links with other disciplines, in ways strongly related to today's medical needs (e.g. biomedicine).

Similarly, the issues of navigation safety (marine, land, air, space) concerning changes in const-ruction and methods of ship conduct need to be related to other disciplines of science, not only with geodesy, cartography and transport.

One can easily prove the transdisciplinary nature of ship navigation safety. Navigation requires close

relations with other fields of science, in various areas of knowledge (Figure 1).

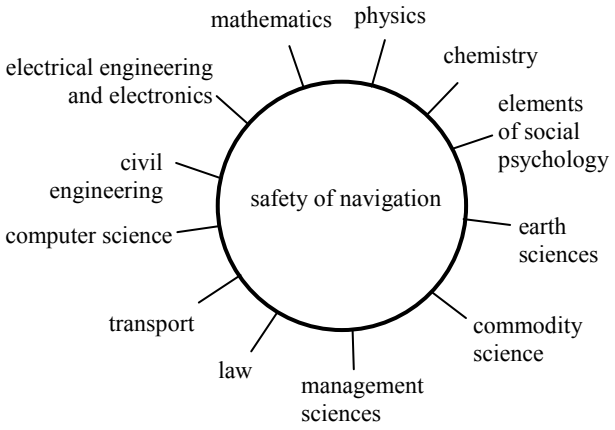

Figure 1. Safety of navigation: transdisciplinary nature of the field

Considering the execution of transport tasks in specific natural environments, with different goals of various types of navigation (transport, fishing, military, tourist and sports, exploratory) one can easily identify the said interrelations with navigation as science. Navigation safety is based on synthesized elements of knowledge and skills derived from various areas, fields and disciplines.

The ways of discovering and formulating scholarly theorems in the theory of navigation, and methods of their implementation are connected with a specific subject of research that is related with other fields of knowledge. The research may be done by constructive and experimental methods, as well as physical or mathematical modelling, which include theoretical and empirical, analytical, simulation and artificial intelligence methods.

Research work in the safety of navigation (marine navigation primarily) encompasses problems of cartography, positioning methods, theory of errors, adjustment calculus, measurement techniques, satellite inertial systems, astronomical and other navigational calculations. Research is being carried out on specific problems of marine traffic engineering. These include:

- dynamics of vessels and the impact of the environment on vessel movement;
- detailed solutions of navigation process optimization (geometrical and hydrometeorological);
- the theory and engineering of autonomous and non-autonomous navigational systems;
- automation of measurements, computations and decision control in navigation;
- development of mathematical models and simulation tests of elements of the navigation process;
- the theory of dead reckoning, including inertial systems;
- synergism (co-operation, interoperability of several components);
- navigational information; etc.

It follows from the relationships presented herein that the classification of scientific fields should be approached to match the conditions of contemporary civilization. The object of cognition applicable in each field or discipline, taking into account the state-of-the-art scientific knowledge of fundamental and applied sciences, is a clue the researcher perceives. This clue, or track, retrieved from the maze of reality and the relationships herein indicated, leads towards interesting areas, determines the sense and significance, renders value to and prioritizes the object of cognition. Therefore, the object of research has its specific character.

It is hard to exclude navigation from the research areas of interest and consideration in view of established civilization changes, especially since, unquestionably, the practical activities of human beings have to make use of the knowledge and experience of other scientific disciplines.

One of the arguments for such a claim is the actual needs for multifaceted navigational solutions in the exploration, exploitation and management of submarine deposits of energy carriers (crude oil, natural gas and coal); chemical raw materials (salt, phosphates, sulphur etc.); construction raw materials (sand and gravel); precious stones: diamond, corundum, topaz or tourmaline etc. as well as amber and polymetallic concretions.

Observing global trends towards an interdisciplinary approach in many fields of science, resulting in astonishing results of transdisciplinary research, it seems apparent that there are many opportunities of utilizing the accomplishments of other sciences to do research in navigation as science.

Therefore, a question arises: what is the sense of demanding navigation to be a separate academic discipline, if the researcher can select any elements of discoveries from other areas, disciplines and fields in his or her research process?

Autonomy of a scientific discipline allows us to select the collaboration with other disciplines to suit the needs resulting from research problems being solved.

Imposing the affiliation of navigation with geodesy and cartography or transport requires that the methodologies of the latter disciplines be used and developed, even though some of their parts are far from nautical issues. It also refers to scientific

terminology. Therefore, not using their methods and terminology means fictitious affiliation, while using them restricts both the development of navigation as scientific discipline and collaboration with other fields of science (Figure 1) in various areas of knowledge.

Scientific autonomy of navigation offers opportunities for creating an original methodology, and application of genuine research methods, matching dynamic developments and social needs.

Today both innovation and research optimization are expected, and to achieve them on a regular basis, transdisciplinarity seems to yield the best results.

Perhaps the existing classification is an artificial form that does not satisfy today's requirements. What if we reserve the science classifications for educational activities and institutions, whereas scientific research will target issues resulting from the economic and social demands of a country and the world?

This author does not attempt a detailed description of the wide topic, but intends to set forth arguments for and provoke a discussion on the need to establish navigation as a separate scientific discipline within the technical sciences (Walczak, 2005, p. 36).

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