Pedagogical Foundations for Effective Competency Building in the Hydrographic and Cartographic Sectors

Sub-Theme: Mapping for Sustained Development

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Abstract— Human endeavor in maritime sectors is ever increasing towards the exploration of oceans for both economic growth and environmental sustenance. The demands on marine geospatial information, its management and promulgation for the purposes of maritime security, resource development and exploitation as well as habitat protection, to list but a few, reiterate the need for competency building in the hydrographic and nautical cartographic sectors.

Standards of competence have been exhaustively defined for hydrographic surveying and nautical cartography by the International Board comprised of eminent professionals representing the International Hydrographic Organization (IHO), the International Federation of Surveyors (FIG) and the International Cartographic Association (ICA) and these standards are disseminated as IHO Publications S-5 and S-8 Category ‘A’ / Category ‘B’ standards respectively.

While the learning content and outcomes have been succinctly defined in the IHO/FIG/ICA standards, the authors suggest that additionally, the training methodology and delivery mechanisms should address the learning styles of the so-called millennial professional which, with increasing dominance, include leading edge technological advancements and internet connectivity, and that these should be built on strong academagogical foundations.

Attempting to build on the significant contribution of the work by the International Board, this paper identifies and classifies the competencies elucidated in the S-5 and S-8 Standards of Competence in terms of knowledge, skills and attitude attributes; suggests suitable learning methodologies to assure achievement of stated learning outcomes and provides an academagogical framework we believe is suitable to leverage technology and build a learning ecology that suits millennial learning styles.

Keywords— Competency building, hydrographic surveying, nautical cartography, marine geospatial information, S-5, S-8, IHO/FIG/ICA, academagogy, millennial learning, standards of competence

I. THE COMPETENCY PIPELINE IN HYDROGRAPHIC AND CARTOGRAPHIC SECTORS

The sciences of hydrography and nautical cartography demand competencies that enable effective conduct of the following broad activities as elucidated by Schiller et al [1]:

- Surveying of waters, and recording of aquatic data;
- Processing of the data, administering the data in information systems, and analyzing the total set of data;
- Visualizing the waters on charts and in information systems, and informing about the waters.

The execution of the aforesaid activities requires building competencies that encompass generic and distinct knowledge, skills and behaviors that translate into consistent performance at work that is worthy of a qualified global professional. Generic knowledge and skills would broadly cover numeracy, geography, science, analysis and problem solving, and computing skills, which form the prerequisites over which the specialisms of hydrographic knowledge and skills is built.

Building a curriculum to address the requirements of the hydrographic and nautical cartographic professionals necessitates articulation of what, why, where, when and how they perform their duties, through which a structured syllabi is evolved. In the present context these have been elaborated in detail by the FIG/IHO/ICA, as Standards of Competence for the hydrographic surveyors (S5) [2] and the nautical cartographers (S8) [3].

Adapting a curriculum to a context requires application of appropriate pedagogical precepts. The context referred here broadly includes, technology, past experience, future expectations, societal and governmental norms, standards of industry, security and environment. Bloom’s taxonomy [4], along with suitable pedagogical constructs, provide a sound framework for implementing a curriculum effectively. The effective delivery of curriculum, however, is still no guarantee for building and nurturing a competent, responsible global professional, for it also depends upon “critical competencies” defined by Gardiner [5] which include:

- Accept ownership and responsibility;
- Ability to act in principled, ethical fashion;
- Skill in oral and written communication;
- Interpersonal and team skills;
- Skills in critical thinking and problem-solving;
- Respect for people different from oneself;
- Ability to change;
- Ability and desire for lifelong learning.

The learning approach must align to the needs of the millennial (defined here as those born after 1980). If millennial are going to form our future workforce, then it
should follow that our policies, methods, and processes need to be millennial-centric, rather than historic. Prensky [6] states, “Today’s students are no longer the people our educational system was designed to teach.” Prensky adds, “the single biggest problem facing education today is that our current teachers, speak an outdated language (that of the pre-digital age), and are struggling to teach a population that speaks an entirely new language.

Surely, as a consequence, our focus needs urgent change. The direction of effort is as important as speed and flexibility in a global context. Employment in future would know no borders, nor have corporate edifices as addresses. Anytime, anywhere, “any-many” would be the workplace of the future! Obviously, the governing rules would change. And the academia of today should become the catalyst of this change.

An effective learning content must conscientiously foster and promote the right Attitude - Skills - Knowledge (ASK) by designing relevant learning tasks that integrate the ASK elements [7]. The learning tasks in turn should realistically simulate the professional and societal environments in which the tasks are to be performed. The challenge therefore is to explicitly identify the learning outcomes and create tasks which will guarantee achievement of the stated outcomes. The triad of the ASK model is depicted in Fig 1.

The learning delivery system should thrive in an ecology that promotes adult to adult learning, also referred in the literature as “andragogy”. The underpinning consideration here is to link the subject matter ‘what is to be taught;’ with the teaching methodology, ‘how is it to be taught’ [8]. In fact, should the subject be formally taught in a conventional sense, or should it be facilitated, where faculty and students are active partners. The change from a teacher-centered learning (pedagogy) to a student-centered learning (andragogy) and thence to self-determined learning (heutagogy) requires a paradigm shift. Academagogy seeks to utilize the appropriate parts from learning theories [9] and blend them in the context where they could be effectively implemented to deliver holistic outcomes.

II. THE ACADEMAGOGICAL FRAMEWORK

The academographical framework hinges on the concept of social constructivism: for one, it addresses the major skill gap of team work in the first time professionals in industry; two, it provides more interaction amongst participants and facilitators, thereby, gives more opportunities for active communication; and three, it uses one of the major strengths of millennial viz., social connectivity round the clock. The salient characteristics of social constructivism [10] that provides the basic foundation to the proposed academagogical framework are depicted in Fig 2.

A conceptual map of the academagogical framework is presented in Fig 3. The map has six stages numbered 1-6, which delineates six stages in which the framework can be developed and implemented.

- Stage 1 is where the Subject Matter Expert (SME) along with the Learning Consultant (LC) studies the prescribed curriculum and crystallizes clear course objectives with measurable outcomes that signal the success of a course;
- Stage 2 is the stage where the course objectives are transformed into specific learning outcomes, clearly identifying the knowledge, skill, and attitude components;
- Stage 3 deals with the mapping of learning outcomes (what needs to be taught) to learning methodology (how it is to be taught). The prescription of academagogy becomes relevant here, for it forces us to select the best learning approaches that suit achievement of the stated outcomes. Our learning approach could select methods using the principles of andragogy and heutagogy;
Stage 4 introduces participatory learning, where both the faculty and students take ownership for successful conduct of the course and have a stake in achievement of the outcomes. The course schedule, timelines, and accountability are fixed and unequivocally stated;

Stage 5 is the stage where actual course delivery begins and progress tracked. The progress is jointly discussed between the faculty, students and the consultant, and course corrections effected as may be necessary;

Stage 6 is the stage of overall review, reflection and feedback so as to make continual improvements to the course content and delivery, keeping in mind advances in technology, process and established best practices.

Stage 1: Distilling course objectives and measurable outcomes

- Given the opportunity to undertake hydrographic surveying for purposes of nautical charting (C), the participant, in the capacity of a team member (A), will be able to apply theoretical concepts and principles of hydrographic surveying and demonstrate skills in capturing and processing survey data (B), which will be verified by a supervisor (D);
- Demonstrate a mastery of the fundamental knowledge and skills (D) required for functioning effectively as a team member (A) in a hydrographic survey team or office, and an ability to integrate and apply them effectively to practice (B) in the workplace that processes and reports survey data (C).

The objective stated above has four distinct parts: (A) Audience (B) Behavior (C) Condition (D) Degree of Mastery.

Some example of the measurable outcomes from the aforementioned objectives can be:

- Number and severity of errors during capture and cleaning of data;
- Number and severity of errors in setting up of equipment, configuration and calibration;
- Degree of confidence and time-taken to complete a specific task;
- Degree of confidence to manage unscheduled changes caused by uncontrollable extraneous factors.

Stage 2: Identify learning outcomes using the ASK model, for example:

- Describe the theory of geodesy and tides (assessing knowledge);
- Recognize factors of risks and safety in boat work (demonstrating evidence comprehension);
- Show how changes in sound velocity affect sonar depth measurement (demonstrating evidence of application);
- Calculate gradient from maps in m, km, % and ratio (demonstrating evidence of analysis);
- Propose solutions to mitigate risks during a small hydrographic survey work (demonstrating evidence of synthesis);
- Assess the importance of quality control in 3D visualization and editing (demonstrating evidence of evaluation);
- Confi gure hydrographic processing software (demonstration of psychomotor skills);
- Set-up the equipment needed for a multibeam hydrographic survey (demonstration of psychomotor skills);
- Conduct a patch test and compute results (demonstration of psychomotor skills);
- Recognize and accept the need for international standards in hydrographic surveying and nautical charting (demonstration of attitude);

The academagogical framework offers three major benefits [11]:

- Promotes joint ownership of outcome based academic curriculum between the learners and facilitators;
- Encourages communication and teamwork;
- Leverages on the millennial need for social connectivity on a 24x7 basis.

More significantly, the framework supports:

- Holistic transformation from using of information to application of wisdom;
- Converting knowledge into action through experiential learning and simulated role plays;
- Nurturing positive attitudes impacting behavioral transformation.

III. APPLYING ACADEMAGOGICAL FRAMEWORK TO A SAMPLE HYDROGRAPHIC SURVEY COURSE

The stages of development of an academagogical framework elucidated above are now being applied to a sample hydrographic survey course. The examples given below are intended to be illustrative and attempt to describe possible alternatives that may be relevant to the context in which the framework is applied.
Stage 3: Mapping learning outcomes to appropriate learning methodologies
Selecting appropriate learning methodologies is the key to achieving learning outcomes.

- For example, under the cognitive domain of Bloom’s taxonomy, knowledge can be acquired by recognizing, describing, and locating (all verbs) hydrographic survey reports (noun). The discussions on the interpretation of such reports can be instructor-led in a class room session (facilitator) where participants can clarify and debate (verbs again) to improve their understanding of the subject;

- In the affective domain, the behaviors that need attention and development relate to: (a) receive – willingness to listen and experience; (b) respond – willing to participate in a group; (c) value – express personal opinions, judgments (d) internalize – ability to reconcile to internal conflicts, adopt belief system;

- In the psychomotor domain, the emphasis is on skills development: manual, intellectual, or computational, which are relevant in modern times. A large part of effective hydrographic survey training is tilted towards skill development.

An effective learning methodology must embrace to deliver outcomes in each of the three domains – cognitive, psychomotor, and affective. Table 1 to 3 summarizes methods that can be applied to align content delivery in line with the Bloom’s taxonomy:

- Table 1: Methodologies for Bloom’s Taxonomy – psychomotor domain;
- Table 2: Methodologies for Bloom’s Taxonomy – cognitive domain;
- Table 3: Methodologies for Bloom’s Taxonomy – affective domain.

<table>
<thead>
<tr>
<th>Class</th>
<th>Actions (verbs)</th>
<th>Evidence of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>Select, list, name, define, memorize, label, identify, locate, recite, state, recognize</td>
<td>events, people, recordings, videos, filmstrips, text, articles, papers, television, podcasts, webinars, paradigms, terms</td>
</tr>
<tr>
<td>Comprehension</td>
<td>match, restate, paraphrase, explain, give examples, defend, distinguish, summarize, interrelate, extend</td>
<td>recordings, plays, story, speech, maps, psychographs, models, study-reports, analogy, summaries, articles, reports, terms</td>
</tr>
<tr>
<td>Application</td>
<td>organize, simulate, generalize, dramatize, prepare, produce, choose, sketch, apply, solve, draw, show, paint</td>
<td>illustration, solution, question, map, project, forecast, diagram, analytical findings</td>
</tr>
<tr>
<td>Analysis</td>
<td>compare, analyze, classify, distinguish, point out, categorize, differentiate, infer, survey, select, prioritize</td>
<td>questionnaire, survey, graph, report, breakdown, defect, case studies, argument, propaganda, statement, conclusion, glossary</td>
</tr>
<tr>
<td>Synthesis</td>
<td>compose, hypothesize, develop, design, combine, construct, produce, plan, create, invent, organize</td>
<td>play, experiment, alternative action, case studies, hypothesis, formulation, book</td>
</tr>
<tr>
<td>Evaluation</td>
<td>judge, relate, weight, criticize, support, evaluate, consider, critique, recommend, summarize, appraise, compare</td>
<td>conclusion, reflection, self-evaluation, recommendation, survey, court trial, standards, guidelines, laws, regulations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>Actions (verbs)</th>
<th>Evidence of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive</td>
<td>ask, listen, focus, attend, take part, discuss, acknowledge, hear, be open to, retain, follow, concentrate, read, do, feel</td>
<td>listen to instructor, take interest in session, take notes, turn up, participate passively</td>
</tr>
<tr>
<td>Respond</td>
<td>react, respond, seek clarification, interpret, clarify, provide other references and examples, contribute, question, present, cite, become animated or excited, help team, write, perform</td>
<td>participate actively in group discussion, active participation in activity, interest in outcomes, enthusiasm for action, question and probe ideas, suggest interpretation</td>
</tr>
<tr>
<td>Value</td>
<td>argue, challenge, debate, refute, confront, justify, persuade, criticize</td>
<td>decide worth and relevance of ideas, experiences; accept or commit to particular stance or action</td>
</tr>
<tr>
<td>Conceptualize Values</td>
<td>build, develop, formulate, defend, modify, relate, prioritize, reconcile, contrast, arrange, compare</td>
<td>qualify and quantify personal views, state personal position and reasons, state beliefs</td>
</tr>
<tr>
<td>Internalize Values</td>
<td>act, display, influence, solve, practice</td>
<td>self-reliant; behave consistently with personal value set</td>
</tr>
</tbody>
</table>

**Table 1: Bloom’s Taxonomy – Psychomotor Domain [12]**

**Table 2: Bloom’s Taxonomy – Cognitive Domain [13]**

**Table 3: Bloom’s Taxonomy – Affective Domain [14]**
Stage 4 and 5: Participatory learning, timelines, ownership, and course delivery

The emphasis in an academagogical framework is on participatory and social learning. With the completion of activities up to stage 3, entire course structure, with objectives, outcomes and methodologies is expected to be finalized and available.

In stage 4, the facilitator along with the learning consultant must discuss with the participants the expectations, modalities of delivery, and assessments to guarantee the objectives set for the course. Participants should be allowed to make choices as to how the course will be delivered, and by whom?

For example, some portions related to the cognitive domain can for example be delivered by the participants as seminars, term papers, articles or newsletters. Learning components related to the psychomotor domain may be delivered as group project work along with peer reviews, on-the-job mentoring or internships; or, developed as open projects in the wiki which may be open to the expert forums for critique and feedback.

The end-result of such discussions with the participants must result in a course schedule that reflects the scope of content, timelines, methods, and accountability. Aspects such as risks, and risk mitigation procedures may also be incorporated in such a course plan. The course delivery must be periodically reviewed both for progress and performance and suitable corrective measures taken to keep the course on-track. A third-party audit will immensely help in maintaining the integrity of procedures, and the quality of training.

The format for creating course schedules and delivery document must at a minimum include:

- Course topic;
- Expected outcomes and type (cognitive, psychomotor, or affective);
- Start and end dates;
- Method of delivery (seminar, group discussion, lecture, demonstration, simulation, case-study, project work, role-play etc.);
- Who will deliver – facilitator, expert from industry or academia, or the participant as an individual or in group;
- Who will assess and how? A structured assessment format must be devised for every course delivery instrument, which is consistent and transparent. The assessment strategy must align to the targeted learning outcomes. A sample of participant’s assessment card is shown in Table 4, which can be refined to suit the context of a course;
- Feedback report after assessments to be used as a de-brief tool;
- Quality check on the performance and achievement of outcomes.

Stage 6: Review, feedback and continuous improvement

A well-designed course with near faultless delivery will still have plenty of room for improvement. The improvements may be necessitated due to changes in technology, revision in software versions, new laws and regulations, environmental imperatives, or simply, because of changed expectations of the end-user. An effective training evaluation system can help in:

- Curriculum/Course Design;
- Curriculum/Course Delivery;
- Assessment;
- Learning Environment.

<table>
<thead>
<tr>
<th>Competency Descriptor</th>
<th>Beginning</th>
<th>Developing</th>
<th>Competent</th>
<th>Accomplished</th>
</tr>
</thead>
<tbody>
<tr>
<td>An ability to apply knowledge of mathematics, science, and hydrographic Surveying</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>An ability to plan and execute a hydrographic survey project to meet specified needs</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Knowledge of contemporary issues</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An ability to use the techniques, skills, and technical tools necessary for professional practice</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An ability to use the Software and computing tools necessary for professional practice</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>An ability to function on teams or multi-disciplinary teams</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to write technical reports (content, grammar, spelling, formatting, referencing)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to make oral presentations (organization, content, delivery)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>An ability to consistently demonstrate professional and ethical responsibility</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Recognition of the need for, and the ability to engage in lifelong learning</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An example of evaluation criteria for ability to write technical reports can be as follows:

- More than 10 grammatical and spelling errors: Beginning
- 6-10 grammatical and spelling errors: Developing
- 2-6 grammatical and spelling errors: Competent
- Less than 2 grammatical and spelling errors: Developing: Accomplished

Please note – each of the competency descriptor can be sub-categorized to make the assessment more objective. For example, ability to write technical reports can have four sub-categories:

- ability to write technical reports (spelling and grammar)
- ability to write technical reports (references)
- ability to write technical reports (formatting)
- ability to write technical reports (content)

Participants’ feedback along with performance reports, the granularity of which can provide great insights on the
course content, delivery and assessment methods is conventional practice. However, to assure the return-on-investment, and more importantly, the return-on-expectations, the Kirkpatrick’s model [16] is useful. The four-stage Kirkpatrick’s training evaluation model in Fig 4 shows the following:

- Descriptor of the four evaluation levels;
- Leading question on training evaluation;
- When should the evaluation be conducted?
- What instruments can be used to conduct the evaluation?

![Figure 4. Four-stage Kirkpatrick’s training evaluation model](image)

**IV. CHALLENGES AND LIMITATIONS OF THE FRAMEWORK**

The crucial challenge in implementing an academagogical framework is to gain the acceptance of faculty and participants. Especially, faculty members in academia who have got used to the so-called Sage on the Stage paradigm, it indeed may well be difficult to accept learners as equal participants in the process of teaching.

Outcome based learning involves intricate level planning and execution in the creation of appropriate tasks, case-studies and project work that have realism in application. The effort should be to incorporate the higher levels of learning of Bloom’s taxonomy (analysis – evaluation – creation) within cognitive domain, and with emphasis on learning by doing for the psychomotor domain.

The main challenge at hand therefore, is that of change management. In this context, the introduction and implementation of an academagogical framework might follow Lewin’s model, as revised and extended by Schein [17].

The key to success of an academagogical framework lies in the quality of the mentoring done by the facilitators. The faculty should be ready to don this new role and earn the confidence of their mentees. Therefore, the framework should initially be restricted to a small class size of where meaningful interaction and mentoring by faculty can take place. Scalability of the model is therefore open to debate.

The learning methodology used in the model puts great onus and accountability of learning on the students. The model assumes that the students are capable of self-directed learning. It is therefore recommended that the initial deployment of this model be applied to technical or professional courses where the learner’s maturity is higher.

The university or the institutes employing the model should have requisite technologies and bandwidth to support eLearning, wiki, blogs and other collaborative learning spaces in the internet. There should also be adequate flexibility in the university or institutions to experiment with fresh approaches and plug and play content and delivery methods to suit a new style of learning.

Lastly, the framework demands an open mindset where innovative ideas thrive.

**V. CONCLUSIONS**

The learning approaches for building competencies in a knowledge-driven society and meeting the aspirations of millennial learners requires paradigm shifts.

In fact, some of the career descriptions in the organizations of the future do not exist today! Therefore, it becomes pertinent that the learning environs remain agile and flexibly respond to the developments, not merely technological, but more importantly, environmental, cultural and societal. The value shifts in the millennial society become powerful drivers of learning impetus and direction.

The academagogical framework presented in this paper is one such effort to bridge competency-gaps while remaining aligned to technology, environmental and societal changes. The framework needs to be validated, and fine-tuned, both in university and higher education settings, as well as, corporate training, especially for entry level professionals.

The authors invite academia and corporate trainers to invoke and experiment with this suggested academagogical framework and build on it from their experiences and feedback from implementation.

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