

TEACHING ‘NATURAL PRODUCT CHEMISTRY’ IN TANZANIA

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ABSTRACT

Natural products ‘historically’ and ‘today’ have vast importance. This article describes the course ‘Natural Product Chemistry’, a new course in the 2011/2012 academic year in the Faculty of Natural and Applied Sciences at St. John’s University of Tanzania. It reveals how the course has been applied to the African and Tanzanian context and expresses the importance of a ‘Natural Product Chemistry’ course within chemical education. This paper also serves as a resource to help other scientists develop a similar course within their context. [*African Journal of Chemical Education—AJCE 6(2), July 2016*]

INTRODUCTION

A simple definition for a 'Natural Product' is a chemical compound or substance produced by a living organism [1] [2]. The term includes complex extracts, and individual compounds and minerals isolated from these extracts. Many of today's pharmaceutical drugs are natural products or based on natural products, for example: (a) Crestor® is the natural product mevastatin, a statin drug, used for lowering cholesterol (b) Finibax® is an antibiotic drug derived from the natural product thienamycin (c) Yondelis™ is the marine natural product trabectedin, a cancer drug [3]. Natural Product Chemistry educational initiatives are not absent from educational institutions around the world. It has been said that in China natural product chemistry is one of the most developed scientific fields and almost every Chinese university has a research or teaching unit for natural product chemistry or chemistry of natural medicines [4]. There is even an educational survey of chocolate: a marvellous natural product of chemistry [5] and more recently academics in Indonesia have developed a mini laboratory project to make a natural product chemistry course meaningful [6].

The cultural context is not often thought about in chemical education. The significance of cultural differences to chemistry learning was highlighted in a Chemistry Education Research and Practice editorial in 2012 'The International Dimension of Chemistry Education Research and Practice' [7]. Furthermore, a recent article 'Chemistry Education Research Trends: 2004–2013' in the same journal stressed the need for more chemistry education research in areas which include culture and philosophy [8]. In a 1999 article titled 'Transcending Cultural Borders: Implications for Science Teaching', Jegede and Aikenhead provided the valuable deduction 'When science culture is in harmony with a learner's life-world knowledge, learning science concepts reinforces the pupils' worldview suppositions' [9].

To bring African culture into education requires originality which includes the realities and needs of living in a world which is closely connected. This paper describes insights from practice. As well as providing an outline for a natural product chemistry course some areas where cultural knowledge has been blended into the course are discussed. The paper therefore has the following three components: (a) Details of the course 'Natural Product Chemistry' (b) Discussing cultural inclusions (c) Reflections from the course instructor.

COURSE DETAILS: NATURAL PRODUCT CHEMISTRY

General Information

The course is an optional course (not core) open to 3rd year (final year) students in the Faculty of Natural and Applied Sciences at St. John's University of Tanzania (SJUT), a private Christian university in Dodoma, Tanzania. This faculty runs a three year B.Sc. (Education) program, primarily training students to be secondary school teachers in Tanzania.

Course Description

By natural products, we mean the molecules of nature produced by living organisms (plants, microorganisms, fungi, insects, animals etc.). This course focuses on the secondary metabolites which give particular species their characteristic features. The study of these natural products has played a major part in the development of organic and medicinal chemistry and we are now starting to understand the important ecological role that these compounds have.

After an introduction the course focuses on the different classes of natural product and this is followed by learning secondary metabolite biosynthesis. Isolation and structure elucidation techniques are then studied. Finally, the application of natural product chemistry to drug discovery is studied.

General Course Objectives

Upon completion of this course students should be able to:

- Know the biosynthetic building blocks to the different classes of secondary metabolites and be familiar with their biosynthetic pathways
- Assign a natural product to a general class of secondary metabolite (and if appropriate to a more specific part of the general class)
- Understand how to isolate a natural product and know some of the techniques used
- Explain the stages of structure elucidation and know some of the techniques used
- Understand the significance of natural products within drug discovery and the valuable knowledge gained from traditional medicine

Lecture Outline

Introduction to Natural Product Chemistry

- What are natural products?
- The history of natural products
- Traditional medicine

The Classes of Secondary Metabolites

- Introduction
- Polyketides and fatty acids
- Terpenoids and steroids
- Phenylpropanoids
- Alkaloids (and specialized secondary metabolites)

The Biosynthesis of Secondary Metabolites

- Introduction
- Polyketides and fatty acids
- Terpenoids and steroids
- Phenylpropanoids
- Alkaloids (and specialized secondary metabolites)

The Isolation of a Natural Product

- Introduction
- Extraction
- Separation and Chromatography

Structure Elucidation of Natural Products

- The stages of structure elucidation
- Stage 1: Preliminary characterization
- Stage 2: Determine the carbon skeleton
- Stage 3: Determine the relative stereochemistry
- Stage 4: Establish the absolute stereochemistry

Application of Natural Product Chemistry

- Drug discovery

There was a wide diversity of resources used in preparing the lectures and here are some of the main ones [3, 10-18].

Seminar Outline

There were six seminars/problem session periods which vary from 1 – 3 hours in length. Each of these seminars require students to have done some prior study in the form of attempting problems or background reading and answering questions. The seminars were as follows:

Seminar 1 – Classes of Secondary Metabolites – Problem solving: the focus was on identifying the different classes of secondary metabolite, the building blocks and the number of units of building blocks; students were given some problems to attempt before the seminar.

Seminar 2 – Biosynthesis of Secondary Metabolites – Problem solving: the focus was on becoming familiar with secondary metabolite biosynthetic pathways and isotopic labelling; students were given some problems to attempt before the seminar.

Seminar 3 – Isolation of Natural Products – Discussion: the focus was on becoming familiar with isolation procedures; students were given a natural product scientific paper to read and asked to come prepared to discuss the isolation of the natural products.

Seminar 4 – Structure Elucidation – Problem solving: the focus was on practicing determining structures of natural products; students were given some problems to attempt before the seminar.

Seminar 5 – Chiroptical Methods in Determining Absolute Stereochemistry – Discussion: the focus is on learning some different chiroptical techniques; students were given material to read with two questions, and asked to come prepared for a discussion.

Seminar 6 – Drugs, Religion and Chemistry in Tanzania – Discussion: the focus was on students learning the connections between different knowledge areas in a culturally relevant natural product drug discovery seminar; students were given a quiz, have prior reading to do, participate in a hands-on-activity with molecular models, and take part in a discussion. This seminar has previously been reported fully in [19].

Students were directed to the following e-journals for supplementary reading [20-21].

Assessment

- End-of-Semester Examination (50% of the overall assessment).
- Coursework (50% of the overall assessment). This consisted of three components:
 - 1) A traditional medicine focused assignment (20%): In academic year 2014-2015 the title was ‘Traditional Medicine in Tanzania: How do Spiritual Beliefs Influence Traditional African Medicine?’ Students were asked to discuss with individuals, read literature and use personal knowledge to write-up a report (1,200 words) responding to the question posed.
 - 2) Class test (20%).
 - 3) A structure elucidation problem (10%).

DISCUSSING THE CULTURAL INCLUSIONS

Religion

Africans including Tanzanians are very religious people [22, 23]. In this course during the ‘Introduction to Natural Product Chemistry’ one major component was ‘The history of natural products’. Throughout history, human beings have relied on nature to provide for their basic needs. This provides a great opportunity to connect Tanzanians to their religious identity by informing students that there are many natural products within the Bible, the sacred book of Christianity, a collection of ancient writings including the books of both the Old Testament and the New Testament. The two examples used in this course were frankincense and olive oil. These were discussed as follows:

- *Frankincense (olibanum), is an aromatic resin obtained from trees of the genus Boswellia and it is used in incense and perfumes. It is obtained from the tree by slashing the bark and allowing the discharged resins to bleed out and harden. The resin has a large acid content including the pentacyclic triterpene boswellic acids. The essential oil of frankincense is*

produced by steam distillation of the tree resin and contains a large percentage (ca. 75%) of monoterpenes and sesquiterpenes. It has medicinal properties and is used in the perfume industry. Frankincense has significance in the Bible. It was an ingredient in the holy incense used in the tabernacle in the wilderness (Exodus 30:34), and was also offered as a gift to the newborn Jesus (Matthew 2:11) [24].

- *Olive oil is obtained from the olive tree (*Olea europaea*), a traditional tree crop of the Mediterranean Basin. Olive oil is produced by grinding olives and extracting the oil. The oil is composed mainly of the mixed triglyceride esters of oleic acid and palmitic acid and of other fatty acids, along with traces of squalene (up to 0.7%) and sterols (about 0.2% phytosterol and tocosterols). The composition varies by cultivar, region, altitude, time of harvest, and extraction process. In the Bible olive oil has been referred to many times for use in offerings (Leviticus 7:12), fuel (Exodus 39:37), anointing (1 Samuel 10:1) and medicinal (Isaiah 1:6) purposes [24].*

There are several other natural products mentioned in the Bible, including myrrh, cinnamon, aloes, cassia, cumin, garlic, hyssop, and more.

Traditional Medicine

Traditional medicine, including its practice, remains a very strong part of Tanzanian culture [25]. Again during the ‘Introduction to Natural Product Chemistry’ in this course there was a strong emphasis on ‘Traditional Medicine’. The following are some of the features studied:

- Various terminology around traditional medicine was defined, for example, herbalism, ethnopharmacology, traditional medical practitioner, and so on. The following definition was given for Traditional African Medicine (TAM): “Traditional African medicine is a holistic discipline involving extensive use of indigenous herbalism with aspects of African spirituality” [26].
- The philosophy of African medical practice being rooted in the African worldview was entered into and the ideas of diagnosis and treatment within African Traditional Religions (ATR) discussed. In ATR the concept of treatment is comprehensive and holistic as the body, mind and soul are treated [12]. There is not one standard way of practicing TAM and there is great variety between countries and tribal groups within countries. Discussions in

class and course assignments revealed that TAM is still very much respected in Tanzania, but at the same time there is an element of suspicion by many. The ‘medical safety of traditional medicine’ and ‘the dabbling with evil forces in traditional medicine’ are both questioned.

- The advances in TAM today were delivered.

- Out of the multitude of medicinal plants in Africa one of the examples used was *Prunus africana*. Traditionally parts are used for a variety of conditions, but more recently the extract pygeum prepared from the bark is used worldwide as an alternative medicine for benign prostatic hyperplasia [27]. Students were informed about the need for conservation in respect to medicinal plants as indiscriminate harvesting endangers plant populations.

- In 2002 The Tanzanian Parliament passed The Traditional and Alternative Medicine Act [28], which became operational in 2005 with the aims of integrating traditional medicine in primary health care and encouraging cooperation between traditional medicine practitioners and western trained doctors [13]. The traditional healers are known to be the source of knowledge on medicinal plants. It is recognized that respect for the knowledge of traditional healers and operational regulations for benefit sharing is something to aspire to and regarded as an essential basis for fruitful cooperation across sectors. This is within the mission of the Convention on Biological Diversity [29].

- The Institute of Traditional Medicine (ITM) at Muhimbili University of Health and Allied Sciences in Dar es Salaam is charged with ‘the responsibility to research into traditional healing systems, in Tanzania, to identify useful practices which can be adopted and also to identify useful materia medica which can be modernized and developed into drugs for use to improve human health’ [14]. The ITM website informs us that Tanzania is estimated to have over 80,000 traditional

healers with varying specialities. Most healers are herbalists using mainly plants and a few animal and mineral products in their practices. The estimated traditional healer:population ratio is 1:400 compared to 1:30,000 doctor to population ratio. It is specified that from the over 12,000 higher plant species growing in Tanzania, at least a quarter of them have medicinal value. Some of the promising medicinal plants for drug production are *Cinchona ledgeriana*, *Artemisia afra*, *Rauvolfia caffra*, *Rauvolfia serpentina*, *Atropa belladonna*, *Catharanthus rosea*, *Pischiera fuchsiaefolia*, *Moringa oleifera*, *Vuacanga africana*, *Prunus Africana*, *Aloe vera*, *Hibiscus sabdariffa*, and *Waltheria indica*.

- The Association for African Medicinal Plants Standards (AAMPS) is a non-profit company registered in Mauritius dedicated to the development of quality control and quality assurance standards for African medicinal plants and herbal products [27]. In 2010, AAMPS published the African Herbal Pharmacopoeia, which provides comprehensive, up to date botanical, commercial and phytochemical information on over fifty of the most important African medicinal plants.

This section on traditional medicine was completed by a statement appreciated by the instructor (M.S.B.) from Richard Onwuanibe [15]:

The strongest argument for traditional medical practice, from the philosophical point of view, is that it is holistic; it incorporates the personal, social, physical, and spiritual aspects of man. This holistic approach to medical practice is what traditional African medical practice can offer to departmentalized and technologically oriented modern practice. While rejecting the superstitious elements of traditional practice, the modern African medical doctor has a gold mine of traditional sources to integrate into his practice.

A Continuous Order of Understanding

As has been revealed in the course details a culturally relevant interactive seminar was delivered 'Drugs, Religion and Chemistry in Tanzania' [19]. This seminar appeals to traditional African thought 'different knowledge areas forming one continuous order of understanding' [30].

During the natural product drug discovery seminar Tanzanian students were able to appreciate how Tanzanian culture (traditional medicine and religion) is connected with the fundamentals of the chemical sciences (molecular interactions) and relevant application of the chemical sciences (in this case natural product drug discovery to combat diseases prevalent in Tanzania). As stated earlier the seminar has been explained in detail elsewhere [19], however, the sequential connections were explained as follows:

- Tanzania has a rich traditional medicine knowledge that can be used to find new medicines;
- There are life threatening diseases in Tanzania which can potentially be combated by natural compounds from endemic medicinal plants;
- Molecular interactions are fundamental to drug action in biological systems;
- Molecular interactions are subject to the ‘laws of nature’ for example electromagnetic force;
- The ‘laws of nature’ are governed by constants (such as Planck ’s constant, charge and masses of electrons, protons etc.);
- The actual values of these constants are unexplained by science, but must have precise values for the universe to work;
- The laws of nature provide a universe which is ordered, consistent and so knowable;
- The religious African sees God (or spirits) as the ultimate cause behind the laws of nature.

REFLECTIONS FROM THE COURSE INSTRUCTOR

In general students appreciated and benefited from the introduction of this optional (elective) course to the curriculum. A number of students in the course evaluation suggested it should be a core course. By including Natural Product Chemistry, breadth was added to students’

knowledge, in an area which is 'currently relevant', 'historically relevant' and 'culturally relevant'. Until now the course has been essentially theoretical and could have improved by including a practical component. Student comments in the course evaluation supported this fact. Having said this, despite the limited laboratory resources (i.e. only flasks, beakers, separating funnels, measuring cylinders, weighing balances, water baths, routine chemicals and solvents, and so on, with no sophisticated items of equipment), in preceding semesters in organic chemistry practicals, students conducted the experiments 'Extraction of Caffeine from Tea Leaves' and 'Isolation of Aliphatic Hydrocarbons from Tomato Paste'. A commonality in course evaluations and class discussions was students' appreciation for gaining knowledge about medicinal plants, their value, and the secondary metabolites which can be isolated and developed into pharmaceutical drugs. Several students expressed the desire to pursue postgraduate studies in the area. At present a curriculum review of the B.Sc. (Education) program is in progress and the plan is for the new course 'Natural Product and Medicinal Chemistry' to be offered to chemistry major students including relevant practical activities. This will replace the current separate courses 'Natural Product Chemistry' and 'Medicinal Chemistry' and will be taught in a way that shows the interrelationship these disciplines possess.

CONCLUSIONS

Natural products remains a strategic field of study, not least in its relation to pharmaceutical research. Herein is an example of a 'Natural Product Chemistry' course. In order for chemical education to be more relevant and interesting, within the world students live, cultural inclusions should be encouraged to enrich the whole learning experience. This will reduce cognitive conflict, harmonizing the science learning with the students own worldview and indigenous knowledge.

The 'Natural Product Chemistry' course presented here was an attempt to do so and included the aspects of 'religion', 'traditional medicine', and 'a continuous order of understanding'.

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