JOURNAL OF CHEMICAL EDUCATION

Technology Report

Cite This: J. Chem. Educ. 2019, 96, 159−164

pubs.acs.org/jchemeduc

Video with Impact: Access to the World's Magnetic-Resonance Experts for the Scientific-Education Community

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ABSTRACT: Magnetic resonance is a powerful technology that has had a major impact across the physical, life, and medical sciences, from chemistry to medical imaging, with ever-expanding applications in new areas as diverse as mining and food science. It is, however, also a difficult subject to teach, as the theory is complex and requires some familiarity with advanced mathematical concepts to fully comprehend. The first encounters of many students with magnetic resonance are often obscured by explanations that make the subject difficult to understand, lack sufficient detail on the underlying principles, and/or are devoid of real-world examples. This initial, frustrating exposure to the subject can result in disengagement and hinder future attempts to grasp key subject matter. Skilled educators with subject expertise are able to present complex material in an engaging and relevant way, but such people are not present in every institution. A solution to this problem is to use online recordings of globally recognized, engaging lecturers. Here, we report a new resource in the form of four high-quality, online lecture series produced by the Australian and New Zealand Society for Magnetic Resonance (ANZMAG), which are presented by some of the world's best teachers and practitioners of magnetic resonance. The target audience includes postgraduates, final-year undergraduates, university teachers, and researchers. The videos are free to access and are designed to teach and reinforce important concepts in magnetic resonance. To date, the four series, each covering a major topic in magnetic resonance and together totaling over 30 h of lectures, have been viewed over 200,000 times in 168 countries.

KEYWORDS: *Upper-Division Undergraduate, Graduate Education/Research, Analytical Chemistry, Distance Learning/Self-Instruction, Multimedia-Based Learning, EPR/ESR Spectroscopy, NMR Spectroscopy, Proteins/Peptides, Spectroscopy*

INTRODUCTION

Magnetic-resonance (MR) spectroscopy is an extremely powerful technique for studying the structure, function, and dynamics of almost any molecule.[1] It has a wide variety of applications in areas that include biology, chemistry, physics, chemical engineering, medical science, food science, and environmental science and, as such, is included in nearly all chemistry and biochemistry university courses.

University students majoring in chemistry are expected to encounter MR throughout their degree, most commonly in units on nuclear-magnetic-resonance spectroscopy (NMR).[2] Contrary to popular belief, a background in quantum mechanics is not required to understand MR.[3] The topic is, however, not simple, and it is sometimes taught with little reference to practical applications outside of organic or biological (particularly protein) chemistry. As a result, many students (as well as many spectroscopists) find MR theory daunting and the subsequent recall and application of the knowledge very difficult.[4] The challenge lies in combining pedagogic skills with subject-matter expertise. Although skilled educators are often abundantly available at universities, experts of the varied fields of MR are far rarer.

There is increasing evidence on the benefits of the use of videos in education to help in understanding difficult concepts, especially for overcoming difficulties in conceptualization.[5,6] MR theory, in particular, benefits from visual cues where complex mathematical representations, which are often taught in text books, can be translated to more intuitive vector representations and simple animations of vector motion. Recorded lectures, furthermore, provide temporal flexibility

Received: July 3, 2018
Revised: October 5, 2018
Published: December 3, 2018

Table 1. Overview of the Magnetic-Resonance Videos Created

Lecturer (Year)	Series	List of Topics (Time in hh:mm:ss)	Number of Views[a]	Total Watch Time (dd:hh:mm)	Ref
James Keeler (2012)	Understanding NMR spectroscopy	Introduction (2:01)	19,753	9:17:52	11
		Energy levels (46:05)	30,960	194:11:10	
		Vector model (1:10:07)	20,863	199:19:39	
		Fourier transformation (42:41)	12,987	82:04:00	
		Product operators I (47:29)	11,679	94:00:47	
		Product operators II (47:25)	8666	69:06:36	
		Product operators III (36:51)	5892	36:23:07	
		Two-dimensional NMR I (57:58)	20,705	130:08:39	
		Two-dimensional NMR II (36:29)	8738	36:08:13	
		Relaxation I (55:53)	12,969	95:11:18	
		Relaxation II (43:10)	5779	35:10:16	
		Relaxation III (51:11)	4672	30:06:08	
		Coherence selection I (53:48)	4166	28:16:18	
		Coherence selection II (44:28)	2718	14:07:26	
		Coherence selection III (29:02)	2242	6:18:11	
Ad Bax (2013)	Dipolar couplings	Residual dipolar couplings: theory and applications I (45:52)	3511	19:04:20	12
		Residual dipolar couplings: theory and applications II (1:03:13)	1379	7:21:43	
Daniella Goldfarb (2014)	Basic and advanced EPR spectroscopy	Introduction to EPR spectroscopy (1:18:06)	18,798	83:08:46	13
		EPR interactions and EPR in the solid state (1:29:10)	2572	16:00:52	
		Nitroxide spin labels and pulse EPR (1:10:52)	1498	8:02:57	
		Double-resonance techniques, DEER, and CW ENDOR (liquids) (1:06:04)	2075	8:14:36	
		Pulse ENDOR (1:19:37)	630	3:08:58	
		ELDOR-detected NMR and ESEEM (1:22:26)	648	3:08:09	
David Wishart (2016)	NMR-based metabolomics	Introduction to metabolomics (55:20)	1150	5:16:29	14
		NMR-based metabolomics (58:03)	536	3:08:09	
		Software and databases for NMR-based metabolomics (44:30)	252	1:07:56	
		Spectral-deconvolution methods (43:19)	288	1:03:12	
		Statistical NMR spectroscopy (45:00)	225	0:16:17	
		Novel NMR methods (55:13)	136	0:17:42	
		NMR and metabolite imaging (48:39)	111	0:10:40	
		Discoveries and applications (58:05)	100	0:13:29	
		Analyzing metabolomic data (49:52)	116	0:15:14	
		Introduction to statistics I (44:30)	137	0:19:02	
		Introduction to statistics II (1:01:31)	112	0:22:51	
		Using MetaboAnalyst I (48:06)	373	1:20:39	
		Using MetaboAnalyst II (52:01)	164	0:23:19	
		Future of metabolomics (43:46)	107	0:17:47	
Sir Paul Callaghan[b]	Principles of NMR and MRI	Precession and resonance (7:19)	236,200		15
		Introduction to nuclear magnetic resonance (6:56)	134,810		
		How the Terranova-MRI works (6:39)	73,334		
		Acquiring a free induction decay (FID) (6:19)	66,113		
		Field homogeneity (5:57)	47,331		
		Spin echoes, CPMG, and T_2 relaxation (10:10)	73,863		
		Measuring T_1 and T_2 relaxation (5:25)	92,718		
		Magnetic-resonance imaging (4:08)	42,284		
		Introduction to *k*-space (10:34)	51,964		
		k-Space in multiple dimensions (8:16)	34,131		
		2D MRI (5:56)	30,747		

[a]Number of views and total watch time at the time of writing (May 9, 2018). Total views of the ANZMAG videos: 207,707. [b]Sir Paul Callaghan was not officially an ANZMAG lecturer; these videos were produced by the MR company Magritek. They are included here because they are similar in aim and purpose to the ANZMAG videos. The viewing figures are from the Magritek website, although the videos were also placed on the ANZMAG YouTube channel as a separate playlist in April 2018.

for students and allow opportunities for reviewing content according to the learner's pace and needs (e.g., a student can view and re-view complex material as many times as desired and skip over content that is already familiar). Videos can

DOI: 10.1021/acs.jchemed.8b00523
J. Chem. Educ. 2019, 96, 159−164

facilitate thinking and problem solving and help students make the connection from visual clues to the memory process and the recollection of new knowledge. More recently, Urban et al.[5] showed that videos can improve students' experience and engage them better with the course content if they see that the content is relevant to their studies.

It has also become increasingly common for lecturers to make use of online material from sites such as YouTube to aid in their own teaching.[7] Many universities also provide facilities for lecturers to be recorded (e.g., Echo 360), but these facilities are generally limited in function and the resulting recordings are unedited, or only available in-house. Open-access recording means that lectures given by high-profile teachers can be made available to a much wider audience.

Although the pedagogic use of film and video has a long history, its widespread use has been limited by production costs and delivery difficulties. While the cost of production has fallen substantially in recent years with the easy availability of inexpensive and high-quality video-recording equipment, the cost of making a high-quality video featuring a particular presenter can still be high when production resources, time commitments, and travel and accommodation for the production team and presenter (who may reside in different cities and continents) are all considered. Professional scientific societies can step in to provide funds and resources to facilitate such recordings, but this is, as yet, fairly rare, with content often restricted to members of the organization that created it.

In this paper, a series of specially created, themed online videos that focus on various concepts of magnetic resonance are presented. These recordings, organized by the Australian and New Zealand Society for Magnetic Resonance (ANZMAG), are designed to supplement classroom teaching and self-learning of magnetic resonance. They may also be of use or interest to teachers and lecturers. Each video series is designed to cover a facet of MR in depth, but each recording can be viewed on its own and in any order to learn about a particular topic. The themes covered so far include the theory of NMR spectroscopy and magnetic-resonance imaging (MRI), residual dipolar coupling (RDC) and its applications with biomolecules, electron-paramagnetic-resonance (EPR) spectroscopy, and NMR metabolomics. A full list of topics is given in Table 1. The intention is to make high-quality lectures available on demand, especially those covering advanced topics for which understanding is enhanced when taught by world leaders in the field. The target audience of these lectures consists of research students, postdoctoral researchers, and scientists new to the field. In addition, the videos can be used for undergraduate teaching, although this is not presently the targeted audience. The ultimate aim is to make high-quality lectures that are freely available and will facilitate the quality teaching of MR worldwide.

■ METHODOLOGY

Background

Since 2012, ANZMAG has invited distinguished international MR practitioners to give series of lectures at venues across Australia, with all costs underwritten by ANZMAG and with support from local ANZMAG members, host organizations (Australian and New Zealand Universities) and industry sponsorship (instrument manufacturers and publishing companies). Visitors are suggested by the ANMAG community and selected by the ANZMAG Board. Each invitee, named an ANZMAG lecturer of the year, is a high-profile member of the worldwide MR community with a reputation for high-quality teaching. The visits take place every 1−2 years.

The first lecture series, with 14 lectures on basic NMR theory, recorded in 2012, was by Dr. James Keeler from Cambridge University. The 2013 presenter was Dr. Ad Bax from the National Institute of Diabetes and Digestive and Kidney Diseases, U.S. National Institutes of Health, who gave two lectures on the theory and applications of residual dipolar couplings. The 2014 ANZMAG lecturer was Professor Daniella Goldfarb from the Weizmann Institute of Science in Israel, who spoke on the topic of EPR. The 2016 lecturer was Professor David Wishart from the University of Alberta, Canada, who spoke on the applications of NMR in metabolomics. A full list of topics of each lecture series is given in Table 1. All lectures were recorded with a live audience and then edited and made available to all, for free, via YouTube.

Video Production

The lectures were recorded with audiovisual equipment that was available from the host institutions or hired from external sources. Typically, two microphones were used during recording: a lapel or lectern microphone and a second microphone placed near the video recorder, which resulted in two sound tracks. The lecture slides were also obtained from the lecturers. The resulting media files (including Powerpoint or PDF slides) were then combined and edited using the comprehensive video-making software Movavi Video Suite (v17.2, Apsiou, Cyprus) or iMovie (v10.1, Apple, Cupertino, CA). Some of the sound clips were additionally processed using the free, open-source, cross-platform audio software Audacity (v2.2.1, freeware) to balance the sound or select which audio track to use. Loud, out-of-place noises, such as the lecturer accidentally hitting the microphone, doors banging, or coughing from the audience, were also removed. Where there were potential ambiguities in the recording, the lecturer was asked to record clarifying words and phrases, and these were then spliced into the main recording. Depending on the sound clips, "averaged" noise from the original recording was added to the new clips so that the end result sounded consistent. Finally, the edited sound track was duplicated into both right and left channels. Once the first editing of videos was complete they were listed privately for ∼3 months for proof-watching by a selected audience. Feedback and suggested changes were incorporated before enabling public access to the videos.

Dissemination

Once the recordings were uploaded for public viewing on the dedicated ANZMAG YouTube channel[8] and organized into thematic playlists, magnetic-resonance teachers and practitioners were made aware of the resource by dissemination of the information on the contents of each video series through ANZMAG and similar societies. An informal e-mail survey was undertaken in April 2018 to ascertain how both academics and students in Australia were utilizing the ANZMAG lectures.

Statistical Analysis of Viewership

Detailed viewership data were exported from the Google Analytics dashboard of YouTube. The number of views and total watch time were stratified according to age, gender, and geography by Google Analytics. The geographic viewership data for each video were collated into a data matrix and normalized to 1. After mean centering and Pareto scaling of all

DOI: 10.1021/acs.jchemed.8b00523
J. Chem. Educ. 2019, 96, 159−164

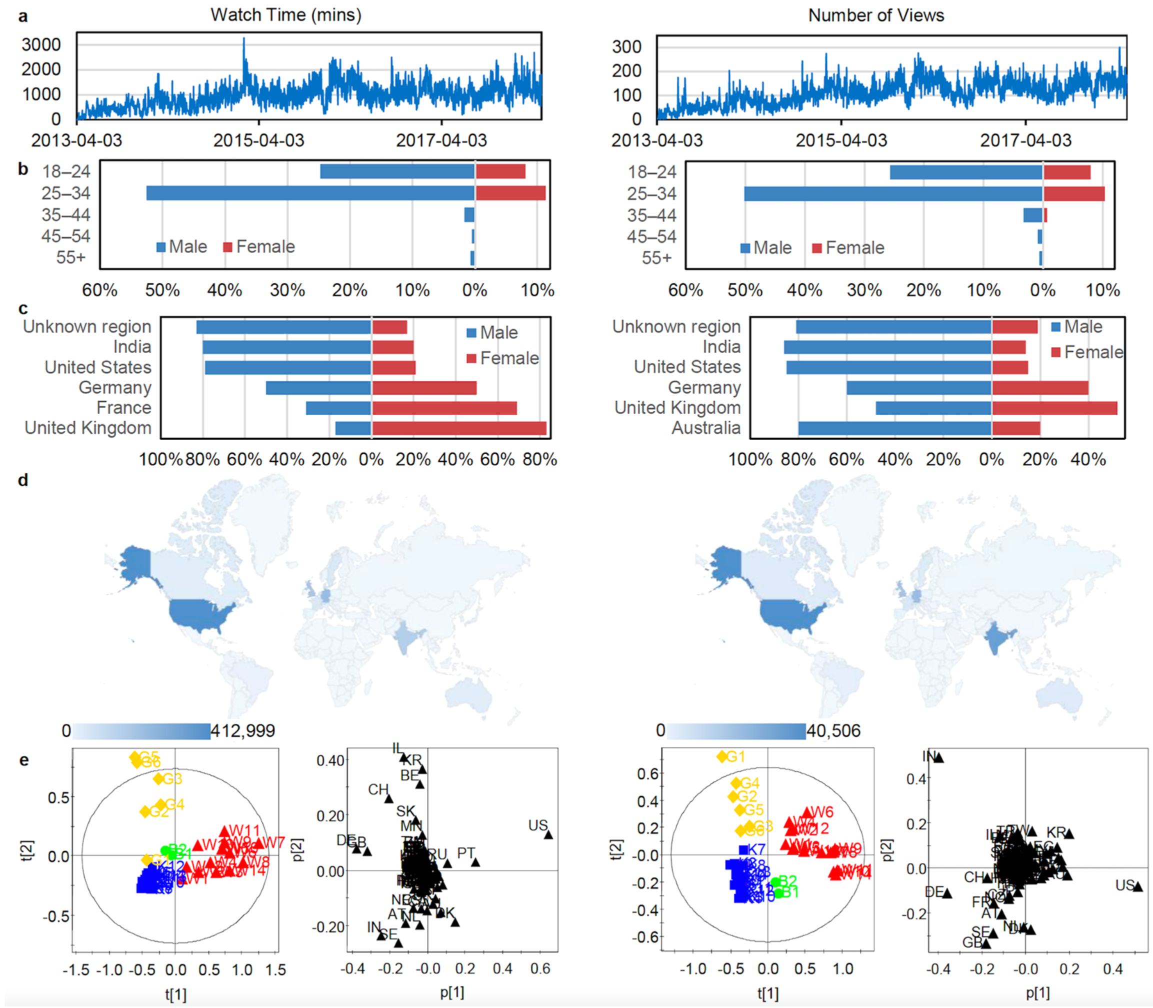

Figure 1. Statistical analysis of ANZMAG viewership based on watch time (left column) and number of views (right column). (a) Daily usage of the channel since its inception (April 3, 2013). (b) Age and gender demographics of viewers who logged in. (c) Gender demographics of viewers who logged in for the top five countries and for the unknown regions. (d) Global distribution of viewership. (e) Systematic differences in global viewership for individual lecture series visualized by principal-components analysis (Pareto-scaled). The left panels in both columns are scores plots showing the differences among individual lectures. Blue squares, James Keeler (Lectures K0−K14); green dots, Ad Bax (B1−B2); yellow diamonds, Daniella Goldfarb (G1−G6); red triangles, David Wishart (W1−W14). The PCA scores for principal components 1 and 2 are denoted by t[1] and t[2], respectively. The right panels in both column are loadings plots showing the countries that are over- and under-represented in the viewership of individual lecture series. Countries are indicated by their two-character top-level internet domain. The PCA-loadings coefficients for principal components 1 and 2 are denoted by p[1] and p[2], respectively.

variables, the corresponding data matrices were analyzed with principal-components analysis[9,10] in the software package SIMCA-P12 (Umetrics AB, Malmö, Sweden), and scores and loadings plots were used to visualize the data.

■ RESULTS AND DISCUSSION

The ANZMAG YouTube channel comprises >30 h of material and represents a significant resource. The associated user comments on the videos show that users have generally found the contents very useful in understanding key concepts. In the past year, the videos have been viewed on average ∼140 times per day, with an average watch time of >1100 min/day, yielding an average watch time of ∼8 min per view (Figure 1a). In total, the videos have been accessed over 200,000 times since the inception of the channel. As a comparison, the Khan Academy NMR video series, has been viewed ∼500,000 times since 2014.

Analysis of the ANZMAG-viewership demographics for those who logged in while viewing the videos (Figure 1) shows that 94.2% of viewers are aged 18−34 years, with 60% in the 25−34 year age bracket, meaning that viewers are most likely to be postdocs and advanced Ph.D. students (Figure 1b). Viewers are ∼81% male and ∼19% female, but women watch the videos longer per view. Demonstrating the global reach, the videos have been viewed in 168 countries. The top five countries are the United States, Germany, the United Kingdom, India, and Sweden, although 23% of views are from “unknown regions” (Figure 1c). The viewing pattern (i.e., number of views and watch times) in India appears to be distinct from those of the other countries in this group of five (Figure 1d), with an average watch time of 4:42 min compared with 9:43 to 13:01 min. The gender ratio differs notably from the average in several countries (Figure 1c): in Germany there is gender parity, whereas women constitute the majority of viewers from France and the United Kingdom and 100% of the viewers in Sweden. There is also a geographical disparity among the individual lecture series (Figure 1e): compared with the global average, Daniella Goldfarb’s lectures are viewed

DOI: 10.1021/acs.jchemed.8b00523
J. Chem. Educ. 2019, 96, 159−164

more in Israel, Korea, Switzerland, and Belgium; David Wishart's lectures are more popular in the United States and Portugal and less popular in Germany and the United Kingdom; and James Keeler's lectures are viewed more in Austria, India, Sweden, and the Netherlands. Interestingly, Ad Bax's lectures are close to the global average.

The James Keeler lectures have been used to educate Ph.D. students and postdocs in NMR and MRI fundamentals at the University of Melbourne. At the Australian National University, RMIT University, the University of Queensland, and the University of Sydney, the lectures are viewed by many local and visiting research students and some visiting researchers. The metabolomics lectures are used as additional resources in two third-year biochemistry courses at the University of Queensland. The EPR lectures are more specialized but have been viewed and found to be helpful by many postgraduates in this area at the Australian National University.

The Sir Paul Callaghan videos produced by Magritek have been used in final-year-undergraduate teaching at the University of Sydney, RMIT University in Melbourne, and the Victoria University of Wellington (VUW) in New Zealand, where they have been very well received. At VUW, the lectures are also used for summer scholarship students, including first-year-undergraduate students.

Informal feedback from undergraduate users at RMIT has been universally positive, with several students commenting that the videos were a great help in learning key concepts as they allowed them to go back and cover key material several times. Several staff members at RMIT noted that it was beneficial to see material presented in different ways and incorporated some of the material into their own lectures. Similar results were reported by educators at the University of Sydney and the University of Queensland.

The MR videos listed in Table 1 are by no means exhaustive. There are many other materials online. For example, the International Society for Magnetic Resonance in Medicine (ISMRM) provides a lot of online content with recorded lectures and learning objectives. However, most of this material is only available to society members who attended the meeting at which the lecture was presented, or it is behind a paywall or designed primarily for a medical audience, not for those interested in science or scientific research. The material is generally available for viewing only after several years following the initial presentation. Other freely available options include Dr. Michael Lipton's "Introducing MRI" video series[16] and Dr. Lars G. Hanson's "NMR and MRI spin dynamics", visualized in the Bloch Simulator software.[17] There are also pay-for-access options, such as Professor Daniel D. Traficante's "Basic Concepts in NMR" training series,[18] but this latter course costs almost $2,000 at the time of writing.

There are also many MR software applications[19] and even mobile apps, such as the Mnova app for NMR-data visualization, processing, and analysis[20] and Steffen Glaser's SpinDrops app,[21] which provides a novel approach to understanding basic and advanced magnetic-resonance experiments and the underlying spin dynamics.

It should be noted that the videos are designed to support, self and small-group learning and teaching rather than classroom teaching. Undergraduate classes may be taught better interactively. Future videos will continue to be developed on the basis of user feedback from both students and teachers. Currently, two series focusing on NMR spin dynamics and relaxation presented by Professors Malcolm Levitt and Arthur Palmer, respectively, are being edited. Future topics are likely to include nonuniform sampling and solid-state NMR spectroscopy. The videos will continue to be advertised in the MR, chemistry, and biochemistry communities, conferences, workshops, and mailing lists to increase awareness of their availability among the intended-user community.

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENTS

The creation of all the video recordings was funded by the Australian and New Zealand Society for Magnetic Resonance (ANZMAG) and the various higher-education institutions who hosted each visiting lecturer with support from industry sponsors (Bruker Biospin and Wiley & Sons, in particular). We also acknowledge the funding from the various higher-education institutions that supported student and staff attendance of the workshops. The authors acknowledge that many members of the ANZMAG society have made significant contributions to this initiative; the presented resource is a product of the society as a whole. We thank the current and former members of the ANZMAG Education committee and the ANZMAG board who are not authors on this paper: Sue Berners-Price, Ian Brereton, Louise Brown, Andrew Coy, David Craik, Norelle Daly, Andrew Dingley, Kirk Feindel, Petrik Galvosas, Dave Gell, Paul Gooley, Leigh Johnston, Glenn King, Philip Kuchel, Roger Ordidge, Steve Pascual, William Price, Caroline Rae, Martin Scanlon, Frances Separovic, Martin Stone, and Allan Torres, who initiated and continue to support the ANZMAG lectures. Particular thanks go to Gottfried Otting, whose involvement has been crucial to the success of the described initiative, for driving, organizing, attending, and encouraging the initiative. We thank all the lecturers involved, as well as James Keeler, Ad Bax, Bill Bubb, Lorna Wilkinson-White, Biswaranjan Mohanty, Greg Pierens, Peta Harvey, and others who watched the early versions of the videos and provided helpful feedback. We thank Bill Bubb for careful proofreading of this manuscript.

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DOI: 10.1021/acs.jchemed.8b00523
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DOI: 10.1021/acs.jchemed.8b00523
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