Chapter 15

Inter-disciplinary Mathematics: Old Wine in New Bottles?

Brian Doig and Wendy Jobling

Abstract This paper attempts to demonstrate that inter-disciplinary mathematics is an old practice, newly rediscovered, and formerly accessible to everyone, but problematised by modern times. Evidence of interdisciplinary mathematics, now often termed STEM, is presented from history and from more recent curriculum documents. Research into the benefits of integrated approaches to STEM education give qualified support to such approaches, and suggests characteristics defining effective interdisciplinary learning. An example of a project-based approach is examined for its contribution to thinking about how inter-disciplinary mathematics might be more generally applied to student learning in Primary and Secondary schools in modern times. Curricular considerations and examples are examined for interdisciplinary possibilities, while some caveats are presented to temper any rush to inter-disciplinarity without due consideration of the consequences.

Keywords Mathematics · Interdisciplinarity · STEM · Caveats

15.1 Early Inter-disciplinarians and Interdisciplinarity

The term “Inter-disciplinary mathematics” is related to, or perhaps subsumes, terms such as polymath from the Greek: πολυμαθής, “having learned much” and scientist, coined from the Latin *scientia* “knowledge, a knowing, expertness” (On-line Dictionary of Etymology, 2015). Either way, we recognize Leonardo da Vinci and Galileo Galilei as polymaths, as inter-disciplinary thinkers. More recently, in the classic work by Bell (1951) *Mathematics: Queen and Servant of Science*, the nexus between mathematics and science was explicit.

Further, within educational curricula at pre-university levels, the use of mathematics in other discipline areas was taken for granted. For example, in the Australian context, the Victorian Education Department guidelines for teachers, *The method of*

B. Doig (✉) · W. Jobling
Deakin University, Melbourne, Australia
e-mail: Badoig666@deakin.edu.au

teaching arithmetic (Department of Education, 1944), teachers of Grade VII were exhorted:

children should actually participate in finding the size of rooms, areas of floors, and the amount of timber required them. The *co-operation of tradesmen could be secured to check the methods adopted* (p. 161) (our italics).

Clearly, it was assumed that tradesmen used mathematics, although their methods may not be, necessarily, those taught in schools. Ten years later, in the Course of Study for Primary Schools, Arithmetic, Grade VII, teachers in rural areas were again reminded that arithmetic must include “Practical investigations and exercises appropriate to the major primary industries of the locality (at least two of which must be taken)” (Department of Education, 1954, p. 4). Of course, one can argue that trade mathematics, or even arithmetic, is not mathematics: but it is *part* of mathematics. Thus, tradesmen, it could be said, continue the tradition of the polymaths and early scientists.

15.2 Modern Times

The modern term ‘inter-disciplinary mathematics’, and related terms, such as STEM (Science, Technology, Engineering and Mathematics) and STEAM (Science, Technology, Engineering, Arts, and Mathematics), have become prominent in recent decades. A notable inclusion in this area is that of technology, often taken to be a reference to digital technologies, rather than technology in its broader sense. This broader sense is, for example, that “technology is the term that includes all the technologies developed and used by people in the purposeful application of knowledge, experience, and resources to create products and processes that meet human needs” (Australian Education Council, 1992).

In Western Australia, the Education Department took the step of defining its technology process strand as designing, making, and appraising (DMA) (Education Department of Western Australia, 1994), to make the study of technology an authentic, real life practice for the students. This meant that technology in Western Australian schools included metal-work, carpentry, jewellery making, pottery, cooking, and even horsemanship.

In 2003 Mason, Mittag, and Taylor, prompted by calls from national mathematics (National Council of Teachers of Mathematics, 2000); and science associations (American Association for the Advancement of Science, 1989), published *Integrating mathematics, science, and technology*. However, while their work was replete with mathematics and science, the technology was restricted to digital technology, effectively only graphic calculators.

15.2.1 *Integrative Approaches to Inter-disciplinary Learning*

Disciplinary Learning

Design Sciences, which, at that time in Greece, he claimed, included architecture, engineering, and even medicine and economics: this was from a perspective that “the mission of the Design Sciences is the design and manufacture of artificial objects, having certain desirable properties” (p. 134). In order to emphasise his claim for the importance of mathematics in the Design Sciences, he took a case from architecture “where the roofs of buildings with wide openings (closed stages, swimming pools etc.) are usually designed in the Vaskoglou (2006) argued that mathematics was important for the form of a saddle, because such type of surfaces have big resistance to bending” (p. 134). This saddle is a hyperbolic paraboloid. A further example cited was that of Markov chains, “a successful combination of Linear Algebra and Probability theory ... [in] Operations Research” (p. 137). Of course, such high levels of integration of the mathematics into the Design Sciences may mean that the mathematics may lose its identity and become simply part of that particular Design Science.

According to Becker and Park (2011) “Science, technology, engineering, and mathematics (STEM) education is a crucial issue in current educational trends” (p. 23), but, that “due to the lack of a comprehensive review regarding the effects of integrative approaches among STEM subjects on academic achievement, many teachers are unaware of the benefits of the integrative approaches for student learning” (p. 24). Integrative approaches are defined by Wells and Ernst (2015) cited by Hayward (2016, p. 15) as technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science, and, or, mathematics education, with the concepts and practices of technology and, or, engineering education. Integrative STEM education may be enhanced through further integration with other school subjects, such as language arts, social studies, art, etc. (Sanders & Wells, 2010).

Note that this definition (clearly and very intentionally) excludes pedagogical approaches that do not situate the teaching and learning of STEM concepts and practices in the context of technological/engineering design-based activity. Furthermore, only technologies that are integral to the doing of designing/making/engineering constitute the T/E component in this definition. For example, simply employing instructional technologies to teach S/M concepts does not constitute the T/E component essential to integrative STEM instruction. According to Laboy-Rush (2011)

[T]hrough an integrated approach to STEM education focused [*sic*] on real-world, authentic problems, students learn to reflect on the problem-solving process. Research tells us that students learn best when encouraged to construct their own knowledge of the world around them ... [and it] is through integrated STEM projects that this type of learning can occur (p. 1).

However, is this claim substantiated? Becker and Park conducted a meta-analysis on some twenty-eight earlier studies, and produced effect sizes for each study. The results were mixed, with some studies showing large effect sizes for some integrative

approaches, and lower effects for others. However, “Students who were exposed to integrative approaches demonstrated greater achievement in STEM subjects” (Becker & Park, 2011, p. 31). An interesting finding was that including mathematics in the mix of integrated subjects lowered effect sizes: “the effect sizes of students’ achievement were small when mathematics was integrated” (p. 31).

Laboy-Rush (2011) cited Diaz and King (2007), who had suggested five characteristics of effective inter-disciplinary (STEM) projects for student learning. In essence, these were that students:

- have a variety of learning tasks to involve them in the learning process;
- receive explicit communications and explanations;
- have opportunities to model solutions, practise solving problems, and receive constructive feedback;
- engage in a student-centred instructional environment that focuses on their interests and needs; and
- receive support for their learning needs.

A recent example of a middle school integrated approach is that of the Prairie River Middle School, in the USA state of Wisconsin. There, the ‘technology engineering’ teacher had a group of students work together to build, from timber, a four metre rowing boat, that was raffled to raise money for charity (Jettinghoff, 2016), “Middle School students use project-based learning to improve math [*sic*] skills and overall academic achievement” (Alexandria Seaport, 2016). Other enterprises involving the building of boats appear to be a popular approach to the integration of mathematics and other STEM subjects.

15.2.2 *Integration of STEM*

A long-standing Victorian STEM competition, involving Primary- and Secondary-aged students in building and racing solar-powered model cars and boats, is an example of an integrated approach to STEM education.

The Victorian Model Solar Vehicle Challenge (MSVC) has been running for over twenty years and is a competition in which groups of students design, make, and race model solar vehicles: these are either wheeled vehicles or boats. In addition, entrants need to provide a poster communicating the building processes: the posters are part of the competition and are judged before being displayed at the challenge event. See www.modelsolar.org.au for more details and video of previous entries. The challenge is conducted at state and national levels, and there is the opportunity for winners to compete internationally too. For example, in the Victorian 2013 challenge, a team from Taiwan competed.

An important aspect of the MSVC is the link to curriculum areas and the integration of them. The main curriculum areas addressed in the MSVC are science, particularly the physical sciences, in which electrical circuits, solar production of electricity, friction, and air or water resistance, are important aspects. Appraise (DMA) process

Fig. 15.1 Model solar boats racing. Photograph: W. Jobling

is critical to producing an efficient model with the equipment and materials available. Testing of proto-types involves data collection and interpretation, as well as drawing logical meanings from the data for improvement to the model. Despite this, the rôle of mathematics is mainly in measuring. The model must keep within the required dimensions, and measurements must be taken during model testing and these data displayed on the poster, as well as interpreted for model improvement.

In terms of technology, the use of the iterative Design, Make, and Appraise (DMA) process is critical to producing an efficient model with the equipment and materials available. Testing of proto-types involves data collection and interpretation, as well as drawing logical meanings from the data for improvement to the model. Despite this, the rôle of mathematics is mainly in measuring. The model must keep within the required dimensions, and measurements must be taken during model testing and these data displayed on the poster, as well as interpreted for model improvement (Fig. 15.1).

Engineering, particularly electrical and mechanical engineering, clearly plays a large rôle in constructing a vehicle that moves by wheels or propellers, and is powered by solar cells. For the model solar boat challenge, in particular, hull shape and the propulsion system are major aspects of the need for some engineering understanding.

Communicating the processes and outcomes of the project, on a poster, helps to draw student attention to their journey to a finished model, as well as how to explain, to a wider audience, the processes and results of STEM projects, and their own learning from the experience.

Is the Solar Challenge project-based learning? If it is, then Donnelly's (2015) question, "Should we 'teach' interdisciplinarity at school?" (p. 3) would be answered

in the affirmative. He suggests that project-based learning would teach students the inter-disciplinary links necessary for inter-disciplinary approaches at University, or at work.

Making these links explicit to students can only be of benefit ... [and] be of benefit to teachers too, working collaboratively across disciplines, sharing knowledge and experiences of pedagogical approaches and joint planning (p. 3).

Apparently, the Singapore Ministry of Education also thinks that inter-disciplinarity across the STEM disciplines is possible, as it announced in 2015 that 42 Secondary schools offer the Science, Technology, Engineering, and Mathematics Applied Learning Programme (STEM-ALP), and that by 2017 half of the 124 mainstream Secondary schools in Singapore would offer the programme.

The skills and competencies to be developed include:

- Scientific inquiry and literacy;
- Reasoning and problem solving;
- Design thinking;
- Computational thinking; and
- Data analysis and the use of technology (Ministry of Education, 2015, p. 4).

While Singapore is not alone in treading the STEM path, Singapore's noted achievements in international academic 'contests', such as TIMSS, suggests that the outcomes of this foray into STEM education through the Applied Learning Programme will be worth watching.

15.3 Caveats

While most of the STEM literature supports some form of integration between the STEM subjects, there is always the possibilities that some integrations may not contribute successful mathematical learning for the students (Becker & Park, 2011); Doig, Groves, and Williams (1996) reported on the mathematization of a science modelling activity with Primary school children aged between 10 and 11 years. The activity involved dropping a 'timer ball' to discover the height from which to drop an object for a falling time of one second. The children experimented progressively with a 0.25 s drop, a 0.5 s drop, and a 0.75 s drop. These data were then graphed and the children noted that the changes in height necessary for a longer falling duration were not linear. For example "Bob said, 'a quarter second is less than half of half a second, so if it worked the same then a whole second should be more than double half a second'" (Doig et al. 1996, p. 4). Further, two high ability 11 year-olds "spontaneously found the differences between the distances [fallen in each quarter second] and concluded that the ball was accelerating" (p. 6). Later, with a group of 10 year-olds, the authors were unsuccessful in convincing the students that this was in fact the case. Thus, Doig et al. noted, that for some children "[t]he process seems almost circular at times—the data obtained from the practical activity is intended to

inform the construction of a model to explain the observed behaviour, yet in order to interpret the data we need to view the data through the window of our existing models” (p. 6).

The Doig et al. example of acceleration, would suggest that inter-disciplinarity may not be a simple matter, and that a re-thinking of curriculum content and sequence may well be needed. In the example above, some preliminary science addressing gravity may have been helpful for the acceleration activity.

A further caveat is the rise of proponents for STEAM, where the ‘A’ stands for the Arts. In this, we find advocates theorizing that STEAM has benefits because “[a]dding the arts into the STEM equation can re-invigorate the platform, providing not only an interesting approach, but also the opportunities for the self-expression and personal connection new generations crave” (Land, 2013, p. 548). While it is sensible for proponents of the Arts to jump on the STEM bandwagon, claims such as Land’s are not easily supported by evidence. For example, Madden et al. (2013) list several innovative integrated tertiary curricula starting up at the time (2013). However, despite the goodwill and efforts of those concerned, claims about the outcomes of courses in creativity integrated into the STEM area are not supported by evidence as yet. Time may yet prove the creators of these programmes to be prescient, but for now, one might say that STEAM is nothing but hot air. Newer calls for other disciplines to be integrated into STEM include religion (STREAM) and history (SHTREAM), and geography, but, at that stage, the acronym becomes unpronounceable!

In some countries, such as Australia, Primary teachers teach all subjects, and the full range of disciplines could be integrated, fully, in theory. However, Australian Primary teachers tend to teach in the silos of discipline areas as much as do Secondary teachers. This is an area needing research, as Primary teachers may be the best placed to adopt inter-disciplinary teaching.

Further, Mercedes-Benz provides an exemplary warning to those urging for, or employing, interdisciplinarity. In the mid-nineteen nineties Mercedes-Benz was keen to develop a car that would be “aerodynamic, safe, efficient, and maneuverable [*sic*]” (Buehler, 2015, p. 1). These criteria led designers and engineers to look to Nature for a possible solution. This, they thought, was to be found in the Boxfish (Ostraciidae Tetrodontiformes), which had remarkable capabilities. For, although box-like as its name suggests, the Boxfish was thought to have excellent hydrodynamic characteristics (low drag), a spacious body, and good stability. Further, the “carapace supposedly had unique, inherent, self-correcting stabilization properties” (Buehler, 2015, p. 1).

Thus, the Mercedes-Benz designers and engineers set out to create the Bionic concept car.

But, researchers at the Universities of Antwerp and Groningen, and the University of California (Los Angeles) reported that the Boxfish shape did not have lower drag, nor did its shape promote stability, but rather, the Boxfish used its inherent instability for fast manoeuvring (Van Wassenberg, van Manen, Marcroft, Alfaro, & Stamhuis 2015).

(For details of the Yellow box-fish, see <https://australianmuseum.net.au/yellow-boxfish-ostracion-cubicus>).

The lesson here is that a little knowledge is a dangerous thing, and one needs to engage with those with real expertise in the particular field. An inter-disciplinary team, rather than everyone a polymath?

The rise, and fall, of the *Sloyd* movement in the late nineteenth and early twentieth century has similarities to the sudden international support for STEM. While *sloyd* still has supporters (see, for example, Noe, 2016), it is hard to imagine how this Scandinavian idea spread like wild-fire internationally. According to Hoffman (1892) the word *sloyd* is derived from the Swedish word *slöjd*, which translates as crafts, handicraft, or handiwork and referred primarily to woodworking. The founder, Otto Salomon, with the financial support of his uncle, started a school for teachers in Nääs in the 1870s. The school attracted students from throughout the world and was active until around 1960.

Educational *sloyd*'s purpose was formative, as it was thought that the benefits of handicrafts in education built the character of the child, encouraging moral behaviour, greater intelligence, and industriousness. *Sloyd* had a major impact on the early development of manual training, manual arts, industrial education and technical education. But, today, in most parts of the world, *sloyd* is long forgotten. Could the "STEMmania" (Sanders, 2009, p. 20) suffer a similar fate? To those involved in the *sloyd* revolution just over a hundred years ago, the answer would most likely be 'yes'. So what stopped *sloyd*?

The opposition to *sloyd* argued that the *sloyd* approach was too rigid, and left no place for creativity, and, like other waves of educational change (for example, the so-called "new maths" of the 1960s) excitement and enthusiasm waned. Salomon argued that learning one craft, wood-working, well, was better than a cursory knowledge of many crafts. Is this a warning for the longevity of STEM?

15.4 Discussion

While claims that mathematics supports human endeavours in science, engineering, and technology are beyond dispute, the implications for educational practice are not so clear. In the curriculum materials presented here, half a century ago mathematics was seen as the tool for other aspects of students' lives. Recently however, this has disappeared, and the rise of calls for STEM education underscore this. However, the question for curriculum developers, teachers, and students is how to install inter-disciplinary mathematics into the fabric of the modern school. Extra-curricular ideas, such as the Victorian Model Solar Vehicle Challenge may point the way for those teachers dedicated enough to make their time and expertise available, but is it sufficient that only a small proportion of students are engaged?

Perhaps, support for a wider audience of teachers to take up inter-disciplinary mathematics with their students lies in more texts such as that of Mason, Mittag, and Taylor (2003), or with projects like the University of California Berkeley's Lawrence Hall of Science's *Science Education for Public Understanding Program* (SEPUP) (2015) materials.

The Ontario, Canada, Ministry of Education introduced an Integrated Curriculum in 2006, and Drake and Reid (2010) maintain that a similar integrated curriculum had existed in Ontario in the 1930s (p. 1). In such integrated curriculum approaches, they claim, “students ... demonstrate academic performance equal to, or better than, students in discipline-based programs. In addition, students are more engaged in school, and less prone to attendance and behaviour problems” (p. 1). Note though, that this is an integration of all school subjects, and is not restricted to STEM subjects. Results were most encouraging, as “[t]eachers and administrators identified student engagement as the most positive aspect of integration ... Strong engagement levels alleviated behaviour problems” (Drake & Reid, 2010, p. 3). Further, “[t]eachers, impressed by the level of classroom discussion, concluded, ‘integrated curriculum lends itself to higher order thinking skills’” (Drake & Reid, 2010, p. 3). However, whether these observations carry through to greater understanding and skills in the integrated subjects is yet unproved.

But, are teachers ready to undertake inter-disciplinary mathematics? Or science? The answer to this question most likely lies within the universities who educate teachers of both mathematics and the other STEM disciplines. An example, of one university approach, is that of the Aggie-Center at the Texas A&M University, where Summer Camps for teachers interested in inter-disciplinary STEM teaching are held each year (Aggie-STEM, 2015). These are well supported and numbers of applicants outruns the number of available places each year.

We believe that we have shown, the path to successful inter-disciplinarity is not without its twists and turns. However, history tells us that the interdisciplinarity of the past was accepted as the norm, however moderate we may now think its level. Perhaps the path to success lies not in more subject areas, nor in teacher specialization, but rather in fewer, key, subject areas coupled with every teacher being an inter-disciplinary teacher. Project work that engages students, and teachers, would be an essential aspect of such an inter-disciplinary approach, so perhaps the saying ‘Old wine in new bottles’ is apt!

However, as with many educational ‘carts’, one should consider the ‘horse’ first. That is to say, that some resolution of the ‘why STEM’ question might assist educators, and administrators, to think clearly about what might constitute inter-disciplinarity in their context. Even if a project-based approach were taken, which projects would satisfy the ‘why STEM’ question. These, and other questions, need to be considered before STEM is over-run with vested interests, rather than educational needs, which has been the fate of other innovations, the digital innovation being a current prime example.

References

- Aggie-STEM. (2015). *Aggie-STEM summer camp*. Retrieved from: <http://aggiestem.tamu.edu/resources/student-resources/summer-camp>.

- Alexandria Seaport Foundation. (2016). *Middle school math*. Retrieved from: <http://alexandriaseaport.org/>.
- American Association for the Advancement of Science. (1989). *Science for all Americans: Project 2061* (Author Ed.). Washington, DC.
- Australian Education Council. (1992). *Technology-a curriculum profile for Australian schools*. Carlton, Victoria: Curriculum Corporation.
- Becker, K., & Park, K. (2011). Effects of integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A preliminary meta-analysis. *Journal of STEM Education*, 12(5 & 6), 23–36.
- Bell, E.T. (1951). *Mathematics: Queen and servant of science*. London: G. Bell and Sons.
- Buehler, J. (2015). *A real drag*. Articles. Retrieved March 23, 2016 from http://www.slate.com/articles/health_and_science/science/2015/03/mercedes_benz_bionic_car_boxfish_stability_and_agility_paradox_finally_solved.html.
- Department of Education. (1944). *The method of teaching arithmetic*. Melbourne: Victorian State Government.
- Department of Education. (1954). *Course of Study for Primary Schools*. Melbourne: Victorian State Government.
- Diaz, D., & King, P. (2007). *Adapting a post-secondary instructional model to K-5 mathematics instruction*. Clemson: Clemson University.
- Doig, B., Groves, S., & Williams, J. (1996). Mathematization: Support or hindrance in young children's science? In: *Proceedings of the Eighth International Congress on Mathematical Education*. Seville, Spain.
- Donnelly, R. (Wednesday, 18 November, 2015). Should we 'teach' interdisciplinarity at school? *The BERA Blog: Research matters*. Retrieved from: <https://www.bera.ac.uk/blog/should-we-teach-interdisciplinarity-at-school?BERA>.
- Drake, S., & Reid, J. (2010). Integrated curriculum. *What works? Research into Practice*, (28). Retrieved from: <http://www.edu.gov.on.ca/eng/literacynumeracy/publications.htm>.
- Education Department of Western Australia. (1994). *Technology and enterprise learning area*. Perth: Education Department of Western Australia.
- Hayward, J. (2016). *An analysis of secondary integrated STEM lesson plans: Common characteristics, learning expectations and the impact from the teacher's definition of I-STEM*. *Curriculum and Instruction*, University of Arkansas. PhD
- Hoffman, B. (1892). *The sloyd system of wood working* (B. B. Hoffman, Trans.). New York: American Book Company.
- Jettinghoff, R. (2016). Launchings. *Wooden boat*, 87.
- Laboy-Rush, D. (2011). *Whitepaper: Integrated STEM education through project-based learning*. Retrieved from: www.learning.com/stem/whitepaper.
- Land, M. (2013). Full STEAM ahead: The benefits of integrating the arts into STEM. *Procedia Computer Science*, 20, 547–552.
- Lawrence Hall of Science. (2015). *Science education for public understanding program (SEPUP)*. Retrieved from: www.seuplms.org/.
- Madden, M., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., et al. (2013). Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Computer Science*, 20, 541–546.
- Mason, D., Mittag, K., & Taylor, S. (2003). *Integrating mathematics, science, and technology*. Boston: Pearson Education.
- Ministry of Education, Singapore. (2015). *42 Secondary schools offering science, technology, engineering, and mathematics applied learning programme (STEM ALP)*. Press releases. Retrieved from: <http://www.moe.gov.sg/media/press/2015>.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: The National Council of Teachers of Mathematics.

- Noe, R. (2016). *Sloyd education theory: Making things with your hands makes you smarter*. Retrieved from: <http://www.core77.com/posts/58789/Sloyd-Education-Theory-Making-Things-With-Your-Hands-Makes-You-Smarter>.
- On-line Dictionary of Etymology. (2015). *On-line dictionary of etymology*. Retrieved from: <http://www.etymonline.com>.
- Sanders, M. (2009). STEM, STEM education, STEMmania. *The technology teacher*, December/January 2009, pp 20–26.
- Sanders, M., & Wells, J. (2010). *Integrative STEM education*. Retrieved from: www.soe.vt.edu/istemed.
- Van Wassenbergh, S., van Manen, K., Marcroft, T., Alfaro, M., & Stamhuis, E. (2015). Boxfish swimming paradox resolved: Forces by the flow of water around the body promote manoeuvrability. *Journal of the Royal Society: Interface*, 12(103). <https://dx.doi.org/10.1098/rsif.2014.1146>.
- Voskoglou, M. (2006, July 9–15). *The importance of mathematics for the design sciences*. Paper presented at the Commission Internationale pour l'Etude et l'Amelioration de l'Enseignement des Mathematiques, Srni, Czech Republic.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.