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TEN TIPS FOR PROMOTING AUTONOMOUS LEARNING AND EFFECTIVE ENGAGEMENT IN THE TEACHING OF STATISTICS TO UNDERGRADUATE MEDICAL STUDENTS INVOLVED IN SHORT-TERM RESEARCH PROJECTS

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Abstract: *This article seeks to present some of the key challenges in facilitating autonomous learning and effective engagement in the teaching of statistics to undergraduate medical students involved in short-term research projects. With a view to addressing these challenges, recommendations for good practice are presented in the form of ten tips for teachers of medical statistics. The ten tips are justified by appeal to the more general educational literature on self-directed learning and engagement. Practical suggestions for the implementation of these tips are provided on the basis of the author's own experience of teaching statistics to medical students who have embarked on 14-week clinical research projects within the 4th year of their undergraduate curriculum.*

Key words: *autonomous learning; effective engagement; online resources; self-directed; quality of statistical practice; undergraduate medical students*

1. Introduction

The educational literature is replete with alternative interpretations of what is meant by autonomous learning (Benson and Voller 1997). More extreme interpretations of this notion are based on the idea of the individual being resistant to external influence at all stages of their learning. The implications for subverting the individual's capacity to construct their own meaning in relation to experiences and concepts are clear. It is understandable why, from this perspective, autonomy may be frowned upon by educational theorists and practitioners as a state of inertia rather than a goal to aspire to.

Consequently, it is important to stress at the outset that whilst autonomous learning as I intend it in the current work is *ultimately* experienced exclusively by the individual learner, it may also be informed through interaction with peers or by reflection on the views of the educator. Socially constructed knowledge, however, must for the autonomous learner in the end be filtered through a personal construct system whereby there is scope for further development of personal nuances and insights.

Thus, I choose to define autonomous learning as a type of learning which is characterized by personalization, self-directedness and less *dependency* on the educator for affirmation, and which therefore enhances rather than hinders the capacity for constructive collaborative participation in the workplace.

The idea that self-directed learning is central to effective engagement with the learning process is well-recognized (see, for example, Ramsden 1992, Bryson and Hand 2007). Nevertheless 'effective engagement' is itself a term which is open to interpretation (Bowen 2005). Thus, I shall take the liberty of using this form of engagement to mean a quality of participation in the learning experience which is transformative. More precisely, the learner is empowered to re-construct what they already knew or believed into a system of beliefs, conceptualizations, values and forms of reasoning which are symptomatic of a more mature state of cognitive development. The sense of authenticity which is derived from autonomous learning as defined above contributes to this process by liberating the learner to view their own perspectives as valid and to embark on a personal learning journey whereby these perspectives must inevitably change over time.

Autonomous learning and effective engagement are not intended here to be ends in themselves. Rather, they are indispensable to responsible decision making in the workplace wherever specialist knowledge needs to be applied within a variety of complex problem-solving contexts. In turn, they ought to reflect transferable graduate skills which are to be fostered in ensuring that the field of learning is practiced soundly and hence with reputable quality.

On the other hand, given the plethora of highly commendable literature by trained statisticians critiquing statistical blunders in the medical literature (Goodman and Berlin 1994, Senn and Harrell 1997, Senn and Harrell 1998, Bland and Peacock 2000, Altman 2002), it may seem surprising that any statistician should wish to entertain the notion of a clinician safely engaging with, or worse still, becoming a self-directed learner within the field of medical statistics! Poor interpretation of statistics can cause much damage to the reputation of statistics and tensions can run high as statisticians become increasingly aware that pleas for greater caution are ignored under the misguided assumption that statisticians, and statisticians alone, are pathologically pre-conditioned to find statistics hard.

Having acknowledged these frustrations, I would argue that statisticians' expectations of the potential of undergraduate medical students in engaging effectively and responsibly with statistics at the undergraduate stage need to be raised considerably and that opportunities must be provided within the curriculum to meet these expectations. Irrespective of whether or not they should choose to pursue a career in research within the workplace, all practicing clinicians will be faced with the challenge of making clinical decisions through "interpreting the evidence" in the available literature with a considerable degree of autonomy and with confidence. The requirements to differentiate between good and bad evidence and to be able to empower patients to make informed decisions based on good communication of findings are unavoidable. The General medical Council (GMC), which is the regulatory body for the medical profession in the UK, has placed an increasing emphasis on the optimization of patient safety as a driving force for quality assurance of medical teaching (GMC 2006), thus reinforcing the importance of the above recommendations.

Moreover, undoubtedly, teachers of medical statistics will wish their students to be optimally engaged. Optimistically speaking, this quality of learning will serve to enhance the quality of the study design and the interpretation of statistics in future publications. It is with this sense of optimism and with a view to disseminating current knowledge and illustrations for practice that the following ten tips for *promoting* autonomous learning and engagement are presented below.

TIP 1

Face the facts concerning inhibitions and the need for stamina in the student's own learning of statistics.

Irrespective of the subject area concerned, an essential part of transformative learning entails maintaining contact with one's true self (Palmer 1998). During one-to-one sessions, the educator is in a prime position to facilitate this through encouraging authenticity on the part of the learner. As Rogers presents it,

> *"the teacher who can warmly accept, who can provide an unconditional regard, and who can empathize with the feelings of fear, anticipation, and discouragement, which are involved in meeting new material, will have done a great deal toward setting the conditions for learning." (Rogers 1967)*

In the learning of statistics in particular, a key message which needs to be communicated is that it is okay, even normal, to find the subject matter difficult. Students accustomed to learning other subjects more progressively or who are less inclined to reason mathematically for a number of possible reasons, including genetic make-up or lack of practise, may need particular reassurance in this respect. Frequently, such students will have been in the habit of performing well and may therefore not have developed the emotional stamina to handle the inevitable time lag which must elapse before they grasp the fundamental concepts and processes relating to the statistical procedures which apply to their research.

Questions regarding levels of confidence, motivation and enjoyment can be incorporated into a pre-meeting questionnaire, as has frequently been the case in the author's own work with undergraduate medical students engaged in 14-week clinical research projects in the form of Student-Selected Components (SSCs) within 4^{th} year (SSC4s). This approach to self-expression can facilitate discussion in terms of improving student comfort levels in terms of engaging with statistics by emphasizing the need for progressive learning and pointing to exemplar reports submitted by students who commenced their study experience from an entirely similar perspective.

An emphasis on the setting of realistic goals is critical at this early stage so as to ensure that the focus for the student can be on what they have accomplished rather than on what has been left undone. Otherwise, the educator is at risk of being designated the role of a 24/7 Accident and Emergency unit, with an unfathomable cost to the depth of understanding for the student and their capacity to engage in lifelong learning in statistics.

TIP 2

Validate the student's capacity to know.

As Baxter Magolda observes (Baxter Magolda 2001), use of current knowledge and experience is perceived as a "sign of respect" and simultaneously furnishes the learner with an awareness of their capacity to enhance their own learning. Likewise, citing medical diagnosis as one of several examples, Boyer observes (Boyer 1990) that the application of one's existent knowledge is a vehicle for "[n]ew intellectual understandings."

The pre-meeting questionnaire referred to earlier may, for example, also include a question on student perceptions of their ability to calculate and know when to use a variety of measures of central tendency and spread. With some careful prompting, follow-up discussions will regularly lead to some degree of recognition on the part of the student as they begin to recognize concepts which they have applied at secondary school level. Invariably, this knowledge will require to be complemented with a sound appreciation of how to choose between different measures according to different characteristics of the data and indeed as to relevant contexts for their application. Nevertheless, it is helpful at this stage to emphasize the value of summary statistics in explaining the characteristics of a study cohort to the reader of the project report, thus reassuring the student that they are already in a position to make a useful contribution to their study.

Much can also be said in favour of validating students' capacities to contribute to their own and others' existing knowledge. The latter validation process can be facilitated by making previous student projects accessible for reference and through adapting more didactic style teaching sessions to incorporate video snapshots of previous students describing key transitions, disproved misconceptions and conquests in their personal learning experiences.

Trusting their judgements as a means of validating undergraduate medical students' capacity to know (Baxter Magolda 2001) may not be a realizable maxim within the field of statistics *per se*. Nevertheless, it is certainly feasible that the foundation can be laid for enabling the same students to select the correct tools to make informed judgements concerning the appropriate choice of statistical methodology as may occur for example when the Bland-Altman procedure is used to compare the interchangeability of cardboard and plastic measuring devices. The student on obtaining their results may be concerned that they have 'failed to' validate the cardboard surrogate in keeping with the aspirations of their supervisor. However, within this context, the student has been introduced to the world of uncertainty where the views of the more experienced clinician are not sacrosanct and hypothesis testing may lead to theory revision. Equipped with the correct statistical tools and skills of interpretation to furnish their evidence base, they are now in a position to use their *own* yardstick of experience to engage in knowledge construction within their chosen clinical field and beyond, whilst sensing that their contribution is capable of being valued.

TIP 3

Provide a comprehensive online Data Preparation Tutorial to counteract psychological barriers to learning created by a formidable data file.

A consistent and often central issue for the student in commencing their statistical analysis is the arrangement of their data in spreadsheets in such a way that these data can be
a) regarded as an efficient and effective means of accessing information which was previously only available in questionnaires, patient records or in an overly comprehensive database
b) readily explained to a statistician
and
c) conveniently analysed using a suitable statistical package such as Minitab or SPSS[2].

(McAleer 1990) advises that when "confronted with statistics" the clinician should "[p]lan well in advance a method that will transfer raw data into a form suitable for statistical analysis." It is often at the stage of data preparation, however, that the greatest scope for anguish in using a statistical package takes place. All too often, spreadsheets involve individual columns containing *conglomerates* of variables such as *presence or absence of analgesic* combined with *type* and *dosage of analgesic used*. Furthermore, this scenario frequently occurs within a context where the student has been encouraged to collect additional data which is not required for their own needs but is of value to future projects. Within this context, it is difficult for the student to embark on the fundamental tasks of identifying questions for investigation and defining related hypothesis (which regrettably but typically takes place after the data have been collected). Moreover, students are often unaware of the value of including a group variable to differentiate between cases and controls for example and therefore have a tendency to create multiple spreadsheets with variations in which columns are included depending on the subgroup to be considered. This adds to the complexity of the preliminary datasheets, and unnecessarily so, leaving the student with an inflated view of what is genuinely required in transferring their data from a package such as Excel to SPSS or Minitab.

With such observations in mind, the author has designed an online Data Preparation tutorial for preparation of data for analysis in SPSS. The Data Preparation Tutorial involves a highly comprehensive PowerPoint presentation covering a wide range of anomalies in Excel spreadsheets based on several years of prior experience in working with students on a one-to-one basis. The anomalies are representative of those which would normally prevent the data from being amenable to analysis in SPSS or be likely to cause obstacles to sub-group analyses or recognition of meaningful research questions once the data had been saved in SPSS format. The presentation is accompanied by sequential spreadsheets in Excel (initial and intermediary stages) and SPSS (later stages) and students are encouraged to prepare their data using this tutorial prior to attending their first appointment.

Where the nature of a student-selected project is such that data need to be collected prospectively and are not therefore prepared in advance, students may also be concerned that they are at a disadvantage relative to their peers in advancing with their project. However, such students are invited to prepare some sample data in Excel using the above tutorial to take them at least to the intermediary stages of data preparation. In turn, further to their first appointment, they are encouraged to use online 'Spreadsheets for Practice' which have been made available to enable them to practice the techniques they can expect to be implementing with their future data. They are also encouraged to touch base again with the statistician should any resultant queries emerge.

Such interventions carry several advantages which are directly related to promoting student autonomy. These include:

i) less repetitive work on the part of the educator in providing individualized support in fine detail regarding alterations which require to be made to satisfy requirements a) to c), above;

ii) empowering the student to use further online resources for analysis of their data prior to arranging their first appointment;

and hence

iii) helping to eliminate the misconceptions that defining hypotheses for 'my data' and statistically analysing these data are formidable or even insurmountable tasks.

TIP 4

Ensure that the student maintains ownership of their own project.

The GMC introduced SSCs in 1993 (GMC 1993) with the intention of ensuring that between a quarter and a third of the UK undergraduate medical curriculum should be devoted to components which are non-optional but within which students could exercise choice in terms of their areas of specialisation.

Thus, the GMC placed an emphasis on the unique capacity of these projects to allow students to "have greater control over their own learning and develop their self-directed learning skills."

In practice, the majority of students choose their SSC projects and corresponding supervisors from an available list, with a target in some institutions of 90% for the proportion of students being allocated their first choice (Riley, Ferrell, Gibbs, Murphy and Smith 2008). In other cases, the student may be allowed to self-propose the topic of the project and approach a clinician who is considered to have considerable expertise in the corresponding field. Moreover, there is considerable scope for flexibility in terms of where to study, although this can vary according to the existing partnerships between universities and industry.

Thus, at the earliest stage of the SSC process there is considerable scope for students to take responsibility for their own learning and indeed to become fully engaged with this activity, provided that choice is based on motivation to learn. Nevertheless, the process from initiation into the SSC experience to submission of the final report is a complex one, ideally involving responsible planning.

Without some early guidance, students, more out of naivety than indolence, can expect to arrive for their first consultation armed with the solitary question – here is my data; how do I analyse it? In making this query, the student is already assuming that the statistical component of their project is a separate entity to be tagged onto their project proper and that the imagination of the statistician may prove an asset in putting the final icing on the cake when the project report is presented for assessment.

In this common scenario, the teacher of medical statistics may be confronted with a plethora of powerful forces enticing them to meet the student's perceived need. At this stage, therefore, it is extremely tempting to offer suggestions as to meaningful associations to test for and effective and efficient means of presenting relationships graphically. If student autonomy is to be realized this temptation is best eliminated by a pragmatic approach rather than conquered by mere will power.

The author has developed an electronic booking form with individual sections for students to complete when requesting their first appointment. By means of these sections the student is invited to specify their own support needs (thus requiring them to consider in advance what they anticipate getting out of their appointment). They are also advised to provide a comprehensive project summary, specifying their key objectives and hypotheses. The electronic form, which has been developed with the support of an experienced Learning Technologist, is designed to arrive via email as an MS Word document and thus in a suitable format for future updating and editing by the statistician during consultations. On submission of the form, the student also receives an automatic reply providing them with their personal electronic copy.

The statistician is then in a position to advise the student in advance of their appointment if further information is required or if the style in which the project details have been presented is inadequate for a meaningful discussion. The scene is therefore set for a productive first session in which the student can be encouraged to set the agenda regarding the subject matter and priorities for the meeting.

More recently, the success of this intervention has been enhanced by the inclusion of an exemplar request form within the system.

TIP 5

Make use of readiness for autonomous learning inventory and self-efficacy questions to assess the preparedness of students for self-directed learning and effective engagement.

For multifarious reasons, students vary considerably in their individual degrees of self-direction (Pratt 1988). In measuring readiness for autonomous learning or engagement, the educator is acknowledging that good teaching requires versatility. Nevertheless, it needs to be emphasized that the type of versatility required here is not to be measured in terms of level of statistical knowledge transmission but rather in terms of the level of pedagogical groundwork that requires to be performed to successfully direct the learner towards more effective engagement or a more self-directed style of learning.

The Self-Directed Learning Readiness Scale (SDLRS) was designed in 1977 (Gugielmino 1977) as a mechanism for quantifying adult readiness for self-directed learning. Since then, its construct validity has been confirmed through numerous studies involving a wide variety of cohorts of adult learners and different statistical techniques (see, for example, Mourad and Torrance 1979, Long and Agykekum 1983, Finestone 1984, Long and Agykekum 1984a, 1984b, Bentley and West 1989, Jones 1992, Baxter Magolda 2001) and is generally accepted as the most valid and widely used instrument of its kind.

The score forthcoming from this inventory is categorized into five classes from low to high, relating to the readiness of the individual for self-directed learning. Based on prior research, it is also regarded as a measure of preparedness for activities involving a high degree of problem-solving, creativity or change. The SDLRS can serve as a diagnostic test for the educator to identify students who are likely to exhibit resistance or disorientation when confronted with a learning programme which requires a high or even moderate level of personal self-management. It may also aid the student in aspiring to more advanced forms of learning provided the necessary teaching resources are in place to facilitate progression to a higher level of self-directed learning (Figure 1).

A further important measurable component in explaining an individual's level of engagement in learning, however, is self-efficacy. Self efficacy has been defined in a number of ways, including as the belief that one can perform a novel or difficult task, or cope with adversity (Scholz, Gutierrez-Dona, Sud and Schwarzer 2002) and as a measure of "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura 1986). Thus, measures of self-efficacy are understood to be predictors of whether individuals are likely to set high goals and how they are likely to respond emotionally and organizationally to a desirable but potentially challenging activity, such as becoming acquainted with statistics. They are also possible predictors of levels of stamina and commitment in the face of discouragements, relapses and challenges.

The commonly accepted measurement of self-efficacy is the General Self-Efficacy Scale (GES) of (Schwarzer and Jerusalem 1995). Like the SDLRS, the construct validity of the GES has withstood extensive scrutiny from a number of sources (Schwarzer and Luszczynska).

Whilst the SDLRS inventory acknowledges self-efficacy in terms of self-concept as an effective learner, important items from the GES are omitted, particularly those relating to the capacity to handle unforeseen difficulties, solve difficult problems and remain focused on personal goals. As the GES comprises only 10 items, with a total average response time of about four minutes, it could conveniently be merged with the SDLRS inventory. However, the change in available response categories for this add-on would need to be highlighted for the benefit of the respondent and would preclude the possibility of conveniently combining scores from the SDLRS and GES in any meaningful sense.

Low self-efficacy scores can assist in promoting positive behavioural changes in individuals identified as being particularly vulnerable to discouragement. In designing a self-efficacy scale which is more effective in the preparation of students for a deeper approach in the learning of *medical statistics* and in maintaining this quality of learning, it is noteworthy that guidelines are available ((Schwarzer and Luszczynska) and (Schwarzer and Fuchs 1996)) for adaptation or extension of the GES to incorporate subscales representative of beliefs about the ability to perform target behaviours within specific contexts. The need for such adaptations in assessing readiness of medical students for self-directed learning in statistics is implicit from Little's observation that 'the learner who displays a high degree of autonomy in one area may be non-autonomous in the other.' (Little 1991)

Moreover, to optimize the use of such a scale in improving student learning it is advisable to ensure that it is itemized to capture the specific type of task to be performed and that it is adapted accordingly as this task is changed. In making such distinctions, however, it is important that the level of specificity is not so high as to preclude its utility beyond the level of an individual institution.

TIP 6

Where constraints on time are considerable ensure that dependency is not a *necessity* of efficiency.

The limitation of time is frequently the precursor to increased dependency on others. Thus, to avoid being late for an engagement, we will pursue the most accessible individual who is qualified to provide directions to the train station or to the appropriate aisle in the department store. The same is true within the domain of student learning.

It is not necessarily the case that comprehensive contents lists for eLearning materials can provide a sufficiently transparent medium for helping the inexperienced learner to know *exactly where* relevant information should be accessed from.

Ironically, attention to level of detail in catering for the varied needs of the masses can result in a formidable spectacle at the level of the *individual* learner. Indeed, for those with lower levels of self-efficacy, a highly comprehensive resource may be perceived as an obstacle to rather than an opportunity for engaging with statistics at a deeper level.

Within this context, the scope for student autonomy and engagement may be severely constrained by the need for the learner to consult the statistician for far more detailed advice than may seem appropriate if the student is ever to appreciate their individual role in knowledge construction. If online knowledgebases are to serve their original purpose, therefore, more work needs to be done to assist the student along the pathway towards more self-directed learning.

Such observations have prompted the author to work with staff from the Learning Technology Section at her home university to develop two online searchable indexing systems for use within EEMeC (the web-based virtual learning environment for the Edinburgh Undergraduate Medical Programme). The indexes are defined separately for her online resources on Questionnaire Design Section and those relating to Frequently Asked Questions on Statistical Design and Analysis. Each index enables students to create a window of URLs to match their own enquiries involving key word searches. These indexes also contain an inbuilt system to enable automatic searching for synonyms based on previously selected key words and can be conveniently updated as new materials are added to the original knowledgebase. Furthermore, the students are encouraged to regard the indexes as being mutually constructed by the educator and the learner. To this end, free text search options are provided to supplement the listed search terms. The free text search options are linked to an automatic reply message for failed searches encouraging the student to specify terms they would like to see added to the online lists of index terms.

TIP 7

Be sensitive to the notion that student autonomy is a process which can be represented by a staging model.

On embarking on a research project, undergraduate medical students are typically unable to gauge the potential level of difficulty and the workload associated with the statistical content of their work. Supervisor aspirations can often be a problem in this context. Recommendations to consult the statistician in retrospect regarding instructions on how to replicate a multivariate analysis discovered in a peer-reviewed journal are wholly unrealistic within a context where students have little recollection or prior knowledge of very basic statistics. Moreover, the process of model building, including the careful screening of potential predictors to include in a multivariate model, and the additional requirement of testing the goodness-of-fit of the model are essential steps for which the student has insufficient time within the context of a short research project.

If common sense is to have any place here, the teacher of medical statistics must take the bull by the horns and develop a learning programme for the student with meaningful learning goals representative of small wins. Where appropriate, these wins should be presented as possible foundation stones for larger successes involving more sophisticated statistical techniques. The student can then be provided with multiple stages at which to exit, where all such stages allow them to attribute meaning to the interpretation of their data but afford progressively greater insights into, for example, what can be inferred about the population based on the sample studied.

Whilst such an approach to teaching statistics can assist in preventing the student learning curve from spiralling out of control and in maintaining student momentum, the difficulty still remains of lack of prior statistical knowledge and in implementing such a strategy, the educator is still very much in control of student learning. This fact is an inevitable consequence of the student having a lack of prior information to process from earlier learning experiences which could provide illumination on their own options. *To ensure that undergraduate medical students are able to choose or even use statistics responsibly in a research project they ought to have had some fundamental experience of how to think statistically but the scene is rarely set to make this ideal a realizable one*. Without intervening through the provision of explicit guidance the educator would therefore succumb to the key pedagogical problem of mismatch between teaching style in terms of control of learning and student preparedness for self-directed learning.

(Grow 1991) usefully highlights the various contexts in which such mismatch can arise with reference to a Stage Self-Directed Learning Model of the sort represented in Figure 1. Mismatch can occur when ellipses on the left and right of the figure are aligned in a different manner to that shown. In the teaching of statistics to medical students it may be the case that the educator is employed to assume the role of the facilitator when due to their lack of preparedness in the area of statistics in particular, students are still at the *dependent* stage.

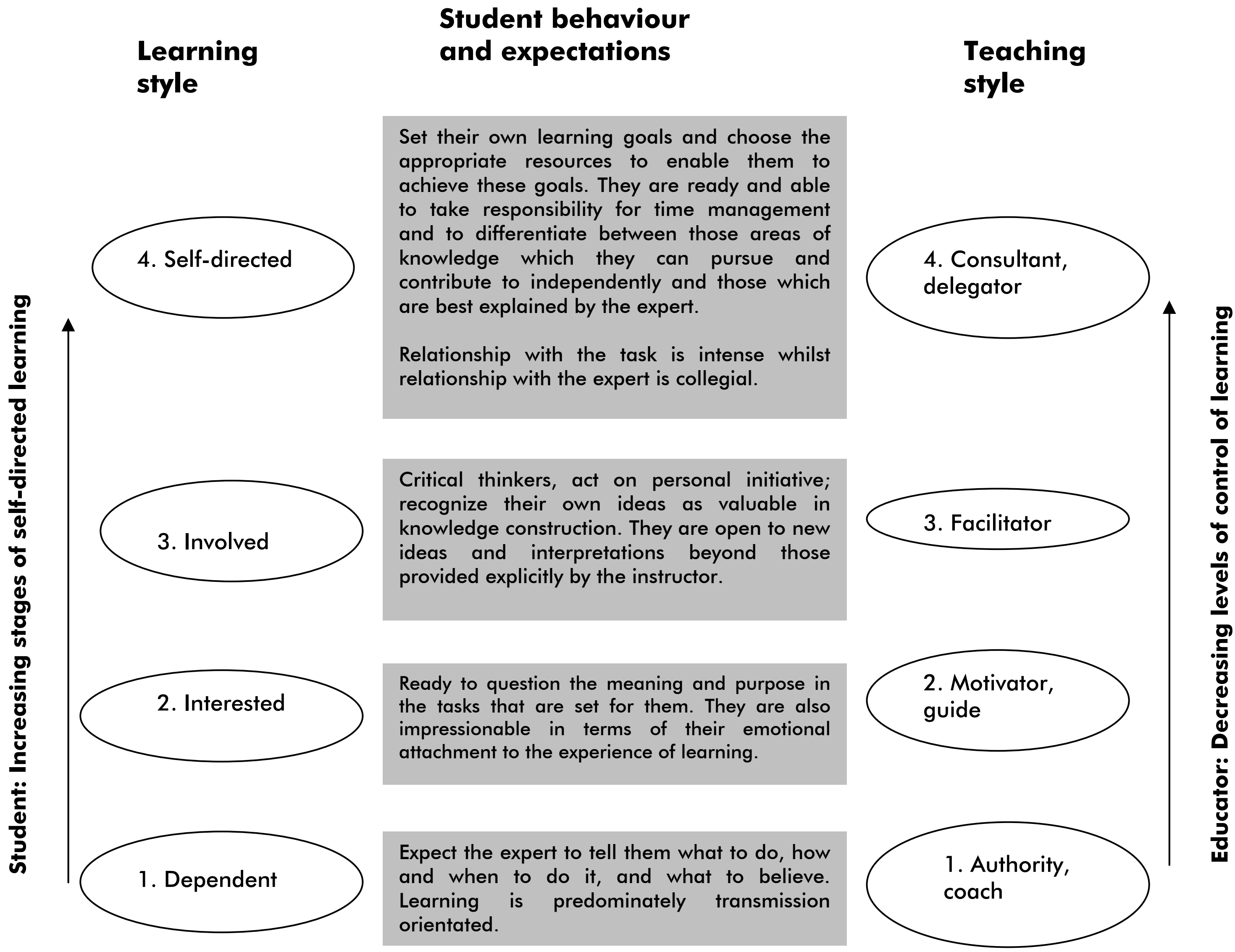

Figure 1. Corresponding learning and teaching styles and student roles in Grow's Stages of Self-Directed Learning

According to Grow's model, it is the responsibility of the educator to manage student learning in such a way that the student's ability to manage their own learning increases.

His underlying philosophy of education includes the doctrines that "[t]he goal of the educational process is to produce self-directed, lifelong learners." The doctrine itself rests on the seemingly paradoxical assumption that "teachers can be vigorously influential while empowering students toward greater autonomy."

Invariably, however, students within any given cohort do not demonstrate the same degree of readiness for self-directed learning. For example, British students from overseas have in some studies shown a tendency to assume that ownership of academic knowledge lies mainly with the host country (Elsey and Kinnell 1990). In turn, they have perceived their responsibility as that of becoming acquainted with British ways of thinking concerning their fields of study. Consequently, they have been less inclined to question the objectivity of beliefs and practices within their host institution and recognize their own capacity for ownership or construction of knowledge. Moreover, in some East Asian countries conformity to popular beliefs and practice is seen as a cultural norm (Ho 2001), (Ming and Alias 2007) and (Alder-Collins and Ohmi 2006) and thus the idea of personalization of learning requires some explaining. Whilst for students from this type of cultural background, adaptation to learning in higher education in Western countries may ultimately prove liberating and intellectually rewarding, it may also prove more challenging due to less preparedness for self-directed learning.

As explained below, the associated need for identifying appropriate teaching and learning styles at an individual level can be addressed through the implementation of carefully designed inventories based on previously validated designs.

TIP 8

Ensure that statistical activities are fully integrated with core learning material rather than bolted on in the form of additional modules with only the appearance of clinical relevance.

In his description of scholarly activities, Boyer (1990) highlights the *application of knowledge* as an activity which promotes student engagement by prompting the student to ask the questions, "How can knowledge be responsibly applied to consequential problems?" and "How can it be helpful to individuals as well as institutions?" In depositing knowledge in the learner's brain, it can be implicitly assumed all too often that the brain then becomes a repository for future consultation. However, even where learners are exposed to multiple perspectives which can add richness to and freedom of choice regarding their own beliefs, it is highly unlikely that the knowledge transmitted will be retained unless it is 'situated in the learners' experiences' (Baxter Magolda 2001) so as to lift the 'barriers between learning and living' (Little 1991).

Application of knowledge is fundamental not only to retention but also to the quality of the learning experience in terms of level of engagement. In order to promote autonomous learning which is not purely assessment driven, it is necessary to protect the student from finding it convenient to treat the statistical content of their course as a separate entity (Entwistle 2005) and from endeavouring to learn without a justification for depth of understanding. Indeed, it has been recognized (Bryson and Hand 2007) that even students with an intrinsic interest in a subject can feel alienated if they are conditioned to focus on the "output orientation" of their degree, including exam performance without a sense of personal commitment. Where statistical assignments are presented simply as an extension to an already highly demanding workload, this sense of alienation can be compounded, and students may resort to procrastination as a temporary means of escape.

It is fundamental, therefore, that the theoretical content being assessed is explicitly presented as part of a process which every student can expect to use in their future professions. In terms of applying this principle to learning approaches, Ramsden observes with reference to Medicine in particular that:

> *"a deep approach typically appears as the establishment of a complex chain of associations which links symptoms to theoretical knowledge." (Ramsden 1992)*

Ramsden's observation is generalizable in Medicine beyond the topic of diagnosis and may in particular be used to refer to the linkage of risk-based concepts in statistics (*including number needed to treat* or *harm*, *absolute risk difference*, *relative risk*, *odds ratio*) and decision making relating to the correct choice of treatment or indeed whether a new treatment ought to be introduced or withdrawn. Through her Higher Education Academy funded project, "Statistics in medicine: a risky business?", the author is currently developing Computer Assisted Learning objects (CALs) which foster a deep approach to learning in Ramsden's sense. The CALs involve integration of real-life case scenarios from recent medical literature with explanations of statistical concepts, structured examples and exercises which provide detailed immediate feedback on understanding.

TIP 9

Ensure that the principle of integration of statistics with core learning material is carried over to formal assessment.

Under Tip 8, above, an emphasis has been placed on promoting a deep approach to the learning of statistics. The intention here is not only to guard against a more surface approach to learning but also, to prevent a purely strategic approach according to which the single intention is to optimize exam performance.

Nevertheless, the undergraduate medical curriculum is typically very demanding in terms of student workload. Moreover, on account of the use of ranking based on student exam performance in current application procedures for UK postgraduate Foundation Year programmes, medical students have the additional pressure of competing with their peers for selection for these programmes.

Thus, students who set out with the full intention of becoming model learners fully engaged with learning processes for all of their course content may be compelled to revert to 'efficiency mode' to manage their own learning packages (Baxter Magolda 2001). During exam preparation, for example, they may be tempted to dissect their carefully integrated body of knowledge so as to eliminate the non-assessable parts, thus sabotaging the original objectives of the educator.

The teacher of medical statistics is therefore obliged not merely to recognize assessment as an essential means of maintaining student momentum in engaging with statistics. Rather, they should also ensure that assessments measure an advanced form of learning according to which the parts are understood in relation to the whole.

Assessment tools should therefore be designed to reinforce the marriage between clinical case scenarios and application of statistics evident in preparatory learning tools. As recommended under Tip 8, above, this can be facilitated in the form of formative assessment through the development of CAL materials involving explicit and immediate feedback to student responses to structured questions. It is important, however, to ensure that subsequent online materials for formal summative assessment are presented in an environment with which the student has already become familiar in the absence of any technological barriers which may impede the validity of the assessment of statistical knowledge.

TIP 10

Engender critical thinking and a sense of uncertainty regarding the presentation of statistics in the medical literature.

By the time they have entered 4th year or ideally, much earlier, one would hope that most medical students will have grown tired of the maxim, "don't believe all that you read."

It is typical and natural, however, for senior students to revert back to a more naïve perspective when presented with a subject area in which they lack the necessary experience to detect conceptual blunders or misapplications of techniques based on reasonably intuitive arguments. They must therefore acquire the art of being legitimately tentative towards the interpretation of data presented in medical publications.

In his list of defining features of a deep approach, as opposed to a surface approach, to learning (Entwistle 2005) includes, amongst others, those of "Checking evidence and relating it to conclusions" and "Examining logic and argument cautiously and critically". For the inexperienced student, the acquisition of these skills can seem so much more worthwhile when presented in an interactive learning environment where misguided conclusions can be seen as a direct hindrance to deriving optimal pathways for patient care. Such an environment is facilitated by the approaches to teaching outlined under Tips 8 and 9, above.

As is the case with the author's own CAL development work, the student can be introduced to Simpson's paradox within the context of erroneous approaches to aggregating risk estimates across studies in the comparison of two competing methods of operative repair. This approach may prove a particularly useful aid to lifelong learning for those who would otherwise have insufficient training to recognize bad practice in the application of meta-analysis techniques to patient data. Moreover, the educator has the opportunity to encourage the learner to recognize the importance of *fully* enlisting a specialist medical statistician at the early stages of a project where statistical work involving a higher level of expertise than that expected from a medical graduate is anticipated. The importance of disseminating this message cannot be over-estimated as a means of reducing opportunities for the compromise of personal professional integrity. Where the statistician is consulted casually, retrospectively or as a mere formality, instances can arise where papers are pushed forward to the submission stage irrespective of concerns raised about the validity of the conclusions they contain in relation to clinical findings.

Even where clinicians have opted for appropriate statistical procedures, however, there is a vital need to train medical undergraduates to critically assess the logical coherence of arguments which formulate the conclusions of a study in a published paper. Such considerations need not be limited to highlighting the well-known distinction between association and cause-and-effect. There is there is also a vital need for highlighting the importance of differentiating between sufficient and necessary conditions, and valid and invalid forms of logical argument and for demystifying the notion of confounding. These needs become particularly apparent where efforts are made to distinguish between the predictor and response variables in affording clinical explanations for the results of hypothesis tests.

Conclusion

Ironically, autonomous learning does not take off autonomously but rather is dependent on the initiative of the educator. Within the context of teaching statistics to undergraduate medical students involved in short research projects, there is incredible scope for addressing the mismatch between students' prior experiences in learning statistics and the role of the educator as a facilitator. Moreover, through the implementation of structured learning strategies, students can be encouraged to engage effectively with statistics. Such strategies can be used develop the capacity to differentiate between good and bad practice. However, they may also be presented as a means of enabling learners to appreciate the complexity of statistics and make responsible decisions regarding the involvement of a professional statistician in more complex work.

If, in the longer term, exposure of medical students to bad statistical practice has a positive effect on patient care, the additional time spent by the educator in designing resources which promote effective engagement and autonomous learning will be of value not only in enhancing the quality of statistical practice in medical graduates but more generally to society as a whole.

The need is also recognized, however, to make provision for the training of undergraduate medical students in the use of sound logical reasoning as a means of ensuring that appropriate inferences are being drawn once suitable statistical procedures have been implemented.

References

1. Alder-Collins, J. K. and Ohmi, Y. **The Process of Critical Enquiry and of Becoming Critical as a Practitioner: The Dawning of a New Paradigm of Global Co-Operation and Educative Understanding or Old Colonial Values Repackaged and Represented?,** British Educational Research Association Annual Conference, 2006
2. Altman, D. G. **Poor-Quality Medical Research: What Can Journals Do?,** Journal of the American Medical Association, 287, 2002, pp. 2765 - 2767
3. Bandura, A. **Social Foundations of Thought and Action: A Social Cognitive Theory,** Prentice Hall, Englewood Cliffs, New Jersey, 1986
4. Baxter Magolda, M. B. **Making Their Own Way: Narratives for Transforming Higher Education to Promote Self-Development,** Stylus, Sterling, VA, 2001

5. Benson, P. and Voller, P. **Introduction: Autonomy and Independence in Language Learning,** in Benson, P. and Voller, P. (eds.), "Autonomy and Independence in Language Learning", Longman, London and New York, 1997
6. Bentley, E. L. and West, R. F. **Structural Analysis of the Self-Directed Learning Readiness Scale: A Confirmatory Factor Analysis Using Lisrel Modeling,** Paper presented at the North American Symposium on Adult Self-Directed Learning, 1989
7. Bland, J. M. and Peacock, J. **Statistical Questions in Evidence-Based Medicine,** Oxford University Press, Oxford, 2000
8. Bowen, S. **Engaged Learning: Are We All on the Same Page,** Peer Review, Analysis, 2005
9. Boyer, E. L. **Scholarship Reconsidered: Priorities of the Professoriate,** The Carnegie Foundation for the Advancement of Teaching, New Jersey, 1990
10. Bryson, C. and Hand, L. **The Role of Engagement in Inspiring Teaching and Learning,** Innovations in Education and Teaching International, 44, 2007, pp. 349 - 362
11. Elsey, B. and Kinnell, M. **Introduction,** in Kinnell, M. (ed.) "The Learning Experiences of Overseas Students", The Society for Research into Higher Education, 1990
12. Entwistle, N. **Contrasting Perspectives on Learning,** in Marton, F., Hounsell, D. and Entwhistle, N. (eds.) "The Experience of Learning: Implications for Teaching and Studying in Higher Education (3rd (Internet) ed.)", Centre for Teaching, Learning and Assessment, University of Edinburgh, Edinburgh, 2005, pp. 3 - 22
13. Finestone, P. **A Construct Validation of the Self-Directed Learning Readiness Scale with Labour Education Participants,** University of Toronto: Doctoral Dissertation, 1984
14. GMC **Tomorrow's Doctors: Recommendations on Undergraduate Medical Education,** 1993
15. GMC **Strategic Options for Undergraduate Medical Education – Final Report,** 2006, Source: http://www.gmc-uk.org/education/documents/strategic_outcomes_final_report_jun_2006.pdf, Last accessed 1 August 2008
16. Goodman, S. N., and Berlin, J. A. **The Use of Predicted Confidence Intervals When Planning Experiments and the Misuse of Power When Interpreting Results,** Annals of Internal Medicine, 121, 1994, pp. 200 - 206
17. Grow, G. O. **Teaching Learners to Be Self-Directed,** Adult Education Quarterly, 41, 1991, pp. 125-149
18. Gugielmino, L. M. **Development of the Self-Directed Learning Readiness Scale,** University of Georgia: Doctoral Dissertation, 1977
19. Ho, I. T. **Are Chinese Teachers Authoritarian?,** in Watkins, D. A. and Biggs, J. B. (eds.) "Teaching the Chinese Learner: Psychological and Pedagogical Perspectives", Comparative Education Research Centre, The University of Hong Kong, China, 2001
20. Jones, J. E. **Validation Study of the Self-Directed Learning Readiness Scale with a Sample of Adult Visual Art Students,** in Long, H. B.and Associates (eds.), "Self-Directed Learning: Application and Research", Oklahoma Research Center for Continuing Professional and Higher Education, University of Oklahoma, Norman OK, 1992, pp. 131 -146
21. Little, D. **Learner Autonomy: Definitions, Issues and Problems 1,** Dublin: Authentik Language Learning Resources Ltd, Trinity College, 1991
22. Long, H. B. and Agykekum, S. K. **Guglielmino's Self-Directed Learning Readiness Scale: A Validation Study,** Higher Education, 12, 1983, pp. 77- 87
23. Long, H. B. and Agykekum, S. K. **Teacher Ratings in the Validation of Guglielmino's Self-Directed Learning Readiness Scale,** Higher Education, 13, 1984a
24. Long, H. B. and Agykekum, S. K. **Multitrait-Multi-Method Validation of Guglielmino's Self-Directed Learning Readiness Scale,** Proceedings of the Twenty-Fifth Annual Adult Education Research Conference, 1984b
25. McAleer, S. **Twelve Tips for Using Statistics,** Medical Teacher, 12, 1990, pp. 127-130

26. Ming, T. S. and Alias, A. **Investigating Readiness for Autonomy: A Comparison of Malaysian ESL Undergraduates of Three Public Universities,** Journal of Reflections on English Language Teaching, 6, 2007, pp. 1-18
27. Mourad, S. A. and Torrance, E. P. **Construct Validity of the Self-Directed Learning Readiness Scale,** Journal for the Education of the Gifted, 3, 1979, pp. 93-104
28. Palmer, P. J. **The Courage to Teach,** Jossey-Bass, San Francisco, CA, 1998
29. Pratt, D. D. **Andragogy as a Relational Construct,** Adult Education Quarterly, 38, 1988, pp. 160-181
30. Ramsden, P. **Learning to Teach in Higher Education,** Routledge, London and New York, 1992
31. Riley, S. C., Ferrell, W. R., Gibbs, T. J., Murphy, M. J. and Smith, W. C. S. **Twelve Tips for Developing and Sustaining a Programme of Student Selected Components"** Medical Teacher, 30, 2008, pp. 370-376
32. Rogers, C. R. **On Becoming a Person: A Therapist's View of Psychotherapy,** Constable, London, 1967
33. Scholz, U., Gutierrez-Dona, B., Sud, S. and Schwarzer, R. **Is General Self-Efficacy a Universal Construct? Psychometric Findings from 25 Countries,** European Journal of Psychological Assessment, 18, 2002, pp. 242 - 251
34. Schwarzer, R. and Fuchs, R. **Self-Efficacy and Health Behaviours,** in Conner, M. and N. P. (eds.) "Predicting Health Behaviour: Research and Practice with Social Cognition Models", Buckingham, Open University Press, 1996, pp. 163-196
35. Schwarzer, R. and Jerusalem, M. **Generalized Self-Efficacy Scale,** in Weinman, J., Wright, S. and Johnston, M. (eds.) "Measures in Health Psychology: A User's Portfolio. Causal and Control Beliefs", Windsor, UK: NFER-NELSON, 1995, pp. 35 - 37
36. Schwarzer, R. and Luszczynska, A. **Perceived Self-Efficacy,** Source: http://dccps.cancer.gov/brp/constructs/self-efficacy/self-efficacy.pdf, Last accessed 1 August 2008.
37. Senn, S. and Harrell, F. E. **On Wisdom after the Event,** Journal of Clinical Epidemiology, 50, 1997, pp. 749-751
38. Senn, S. and Harrell, F. E. **On Subgroups and Groping for Significance,** Journal of Clinical Epidemiology, 51, 1998, pp. 1367-1368

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MacDougall M, Riley SC, Cameron HS, McKinstry B **Halos and horns in the assessment of undergraduate medical students: a consistency-based approach**, Journal of Applied Quantitative Methods 3, No. 2, 2008, pp. 116-128. Link
Kung JWC, MacDougall M, Madhavan KK, Garden OJ, Parks RW. **Predicting survival in patients with hepatocellular carcinoma: A UK perspective,** European Journal of Surgical Oncology 33, No. 2, 2007, pp. 188-194. Link

Dorward DA, Thompson AAR, Baillie JK, MacDougall M, Hirani N. **Change in plasma vascular endothelial growth factor during onset and recovery from acute mountain sickness,** Respiratory Medicine 101, No.3, 2006, pp. 587-594. Link

Todd AJ, Leslie SJ, MacDougall M, Denvir MA **Clinical features important for the diagnosis of infective endocarditis in the modern era,** Quarterly Journal of Medicine, 99, No.1, 2006, pp. 23-31. Link

MacDougall M, Smith R, Scott M. **Comprehensive sensitivity analysis of an SO_2 deposition model for three measurement sites: consequences for SO_2 deposition fluxes,** Atmospheric Environment 39, 2005, pp. 5025-5039. Link

Challis N, Cox W, Gibson I, Golden K, MacDougall M, Parsons S, Stirling D. **Action Research into Effective Student Support in Mathematics,** Proceedings of the Thirtieth Undergraduate Mathematics Teaching Conference, 2004, pp. 59-72. Link

Simpson D., Tuovinen J.-P., Ashmore M.R., Emberson L.D., MacDougall M. and Smith R.I., **Stomatal ozone uptake over Europe: preliminary results,** Technical Report 2002a, in: "EMEP MSC-W Report 1&2/2002, Transboundary acidification, eutrophication and ground level ozone in Europe". EMEP summary report 2002, Norwegian Meteorological Institute, Oslo, Norway, pp. 63-71. Link

[2] "SPSS" denotes "Statistical Package for the Social Sciences".