Framing Professional Learning Analytics as Reframing Oneself

Simon Buckingham Shum, Allison Littlejohn, Kirsty Kitto, Ruth Crick

Abstract—Central to imagining the future of technology-enhanced professional learning, is the question of how data is gathered, analysed and fed back to stakeholders. The field of Learning Analytics (LA) has emerged over the last decade at the intersection of data science, learning sciences, human-centred and instructional design, and organisational change, and so could in principle inform how data can be gathered and analysed in ways that support professional learning. However, in contrast to formal education where most research in LA has been conducted, much work-integrated learning is experiential, social, situated and practice-bound. Supporting such learning exposes a significant weakness in LA research, and to make sense of this gap, this paper proposes an adaptation of the *Knowledge-Agency Window* framework. It draws attention to how different forms of professional learning locate on the dimensions of learner agency and knowledge creation. Specifically, we argue that the concept of "reframing oneself" holds particular relevance for informal, work-integrated learning. To illustrate how this insight translates into LA design for professionals, three examples are provided: (1) analysing personal and team skills profiles (*skills analytics*); (2) making sense of challenging workplace experiences (*reflective writing analytics*); and (3) reflecting on orientation to learning (*dispositional analytics*). We foreground *professional agency* as a key requirement for such techniques to be used effectively and ethically.

Index Terms—Learning Analytics; Professional Learning; Self-Assessment Technologies; Agency; Reflection; Skills Analytics; Writing Analytics; Dispositional Analytics

I. INTRODUCTION

Professional learning can be described as "the activities people engage in to stimulate their thinking and professional knowledge, to improve work performance and to ensure that practice is informed and up-to-date" [4]. These activities sometimes consist of formal education and training, such as workshops or courses that are structured and assessed around pre-defined outcomes, and some professionals (e.g., teachers, architects, financiers, doctors) are obliged to engage in regular, formal professional learning to retain their professional accreditation.

While formal learning of codified, structured knowledge can support aspects of 'business as usual', broader and more embedded forms of learning are needed for innovation and continual improvement in work. Work-integrated professional learning, evolving new practices while working 'on-the-job', is a critical component for innovation [5]. Arguably, most professional learning happens through everyday work activities and social interactions, such as collaborating with a more experienced colleague, or watching a colleague carry out a work task ([6], [7]), and forms of work-integrated learning like these are an important part of adopting new practices and developing innovations at work [8]. There are three important characteristics of work-integrated professional learning that distinguish it from formal learning. First, professionals must self-regulate their learning through forms of active agency, rather than relying on a teacher to signpost and scaffold what is to be learned. Second, learning objectives usually align with work needs and business strategy, rather than being pre-determined through a course curriculum. Third, by its very nature, work-integrated learning is shaped by the workplace environment, meaning there is a direct relationship between the workplace context, and how and what professionals learn at work [9]. Therefore, to understand how professionals learn, and how to support their learning, it is essential to take into consideration the context within which learning and work is taking place. However, most educational research focuses on formal, classroom-based education and training, leaving work-integrated learning under-theorised and under-researched [10].

The field of Learning Analytics (LA) has emerged over the last decade at the intersection of data science, learning sciences, human-centred and instructional design, and organisational change, and so in principle, could support professional learning by providing insights and feedback about professional learning to stakeholders. The field now covers a diverse array of computational techniques for analysing myriad forms of learning data, in order to provide insight to different stakeholders including learners, educators and leaders ([11], [12]). However, like educational research, LA is largely dominated by applications in formal education, raising the question of whether LA can translate to the more experiential, social, situated and practice-bound world of work-integrated, self-regulated learning. This paper makes the case for a

S. Buckingham Shum is with the Connected Intelligence Centre, University of Technology Sydney, PO Box 123, Broadway, Ultimo, NSW 2007, AUS (e-mail: Simon.BuckinghamShum@uts.edu.au).

A. Littlejohn is with the UCL Knowledge Lab and Institute of Education, University College London, 23-29 Emerald St, London, WC1N 3QS, UK (e-mail: Allison.Littlejohn@ucl.ac.uk).

K. Kitto is with the Connected Intelligence Centre, University of Technology Sydney, PO Box 123, Broadway, Ultimo, NSW 2007, AUS (e-mail: Kirsty.Kitto@uts.edu.au).

R. Crick is with WILD Learning, White Hart House, 1 Abson Road, Pucklechurch, Bristol, BS16 9RH, UK, and the Connected Intelligence Centre, University of Technology Sydney (e-mail: Ruth.Crick@wildlearn.co.uk).

particular strategy to designing LA that recognises the critical importance of professional identity and agency in work-integrated learning, specifically, the role that data-informed, automated feedback can play in provoking productive reflection that leads to "reframing oneself" as part of one's professional growth. The paper therefore contributes to this special issue by considering a particular intersection of computing and data science methods with learning theories, our understanding of professional learning and how people learn through work.

The paper is organized as follows: Section II expands on the distinctive features of professional learning, before Section III introduces the *Knowledge-Agency Window (KAW)* framework to help differentiate the forms this can take. Section IV then uses the KAW to map current literature on workplace/ professional LA. Section V establishes the importance of learners' sense of identity, which motivates a focus on "reframing oneself" and on LA that works on data intentionally provided by the learner for this purpose. Moving from concepts to practical design, Sections VI-VIII present three examples of how this approach to LA can be interpreted, namely, Skills Analytics, Reflective Writing Analytics, and Dispositional Learning Analytics. Section IX concludes with a discussion of the core concepts, recognition of the limitations, and opportunities for future research.

II. PROFESSIONAL LEARNING

In the introduction, we summarised three distinct characteristics of work-integrated, professional learning, which we now expand upon. Each individual's capacity to learn is influenced by a combination of psychological (cognitive, volitional and affective), behavioural and environmental factors that form the foundation of self-regulated learning [13]–[15]. Some factors can be improved through practice, such as setting learning goals or switching approaches to learning if a current strategy is not proving effective. Other factors are influenced by affective characteristics, for example the motivation to learn, interest in what is being learned, or self-satisfaction [16]. Self-regulation blends deliberative and non-deliberative cognitive engagement [16], which is characteristic of workplace learning. Thus, these factors are important in professional learning situations where individuals rely on internal drive, personal agency and self-regulation ability to apply newly-learned knowledge to work [17].

This form of emergent learning is complex and requires a sound ability to self-direct one's learning. For example, professional training programs tend to promote understanding of professional knowledge, skills and values, but applying these a new context can be challenging since workplaces have varying cultures, values and priorities, making each context unique. Guile [18] terms the process through which professionals share, evaluate and adapt the skills and knowledge they bring, from both formal learning and previous work experiences, "recontextualisation". In this regard, technology systems that support the development of self-directed learning amongst professionals have the potential for substantial and sustained impact, but at present little is known specifically about self-regulated learning in workplace contexts

[19].

Work-integrated learning objectives are aligned with work goals, such that both are shaped by a shared purpose which informs what counts as a successful learning outcome in that particular context [20]. Professional learners have to 'chart' their learning needs, align their learning goals with work needs and tasks. As these needs change, learners must reframe their work and learning goals. This need to chart and continually reframe is a critical for business innovation and transformation. For transformation, meta-cognitive, meta-affective and meta-relational learning processes, such as self-efficacy, self-leadership and collaborative problem solving are important. The individual's and the team's purpose, and learning trajectories need to be continuously aligned to the organisation's purpose, and re-adapted as goals and strategies at work change [21].

In summary, formal education tends to be framed as the assimilation of prescribed knowledge. In contrast to this, when professionals learn on the job, they must become active agents, setting their own learning goals and self-regulating their learning. It is important to consider how individuals and teams are able to mobilise their agency to identify, select, collect, curate, re-structure and re-present existing funds of knowledge. A challenge for Learning Analytics is how these core learning processes may be scaffolded, supported and enhanced in the context of the workplace.

III. THE KNOWLEDGE AGENCY WINDOW (KAW)

Today's workplaces are continuing to increase in complexity. As the World Economic Forum describes in 'The Future of Jobs' [22] these conditions require broad and long-term changes to basic and lifelong education systems, along with urgent and focused re-skilling efforts required in each industry. To learn how to adapt to new forms of work, professionals need to develop a range of critical 'soft skills' such as self-awareness and self-leadership, emotional intelligence, relationships and complex problem-solving capabilities.

Critical though these are, little attention has been paid to how professionals develop these over their employment trajectory. Building on a long-term study of the development of systems engineering competencies in the engineering professions [23], [24], McDermott, *et al.* [25] proposed that these can be abstracted into three broad categories: *self-leadership, learning relationships* and *complex problem solving.* These reflect a holistic view of the professional as someone with *agency and self-identity*, located in a *relational context* with *real-world complex problems,* which need to be identified, addressed, and solved through the generation of new knowledge. We propose that these changes require a systematic adaptation in how professional learning is structured and scaffolded in the workplace, and that LA offers potential to scaffold this agency.

In the context of university engineering education, prior work by Crick, *et al.* [1] has developed the *Knowledge-Agency Window (KAW)* summarised in Fig.1, which focuses on the two dimensions of (i) the degree of *agency* that students are given in any context and (ii) the degree to which the knowledge they
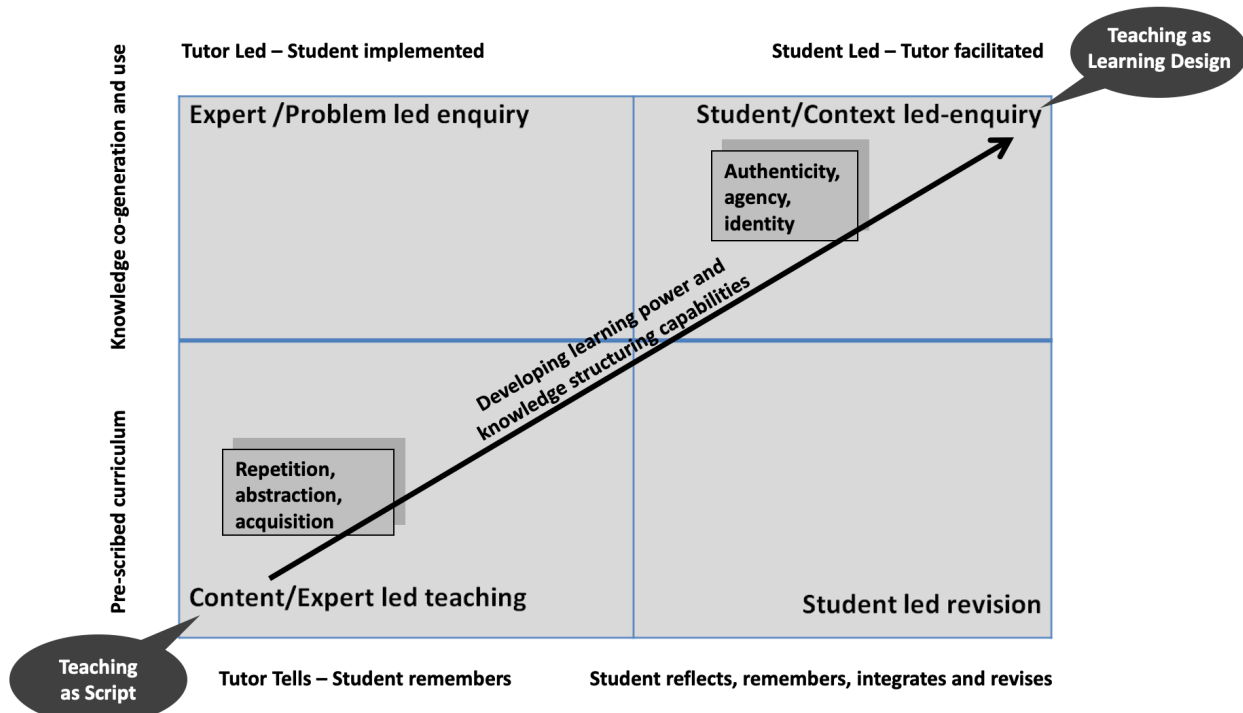
Fig. 1. The *Knowledge-Agency Window* as originally developed in the context of enriching engineering degree programs [1].

must learn is *prescribed/co-generated*. The former draws on purpose and identity – always located in an experiential and narrative context, while the latter has to do with the sequencing of students' encounter with the formal knowledge base of the curriculum. All four quadrants are important, but the top-right quadrant has been most neglected in engineering (and indeed, in much formal education in other contexts). Developing learning designs and analytics to inform that pedagogical shift has been the focus of a 20-year research program [1], [26]–[28].

Taking inspiration from this work, we considered that a contextualised version of the KAW might provide a helpful way to make sense of professional learning and analytics situated in the workplace. As we reflected on the different forms of professional learning, this led to an adapted version of the KAW (Fig. 2) locating four different types of professional learning framed by the two axes: the *spectrum of professional agency* required and the *spectrum of knowledge prescription/creation*.
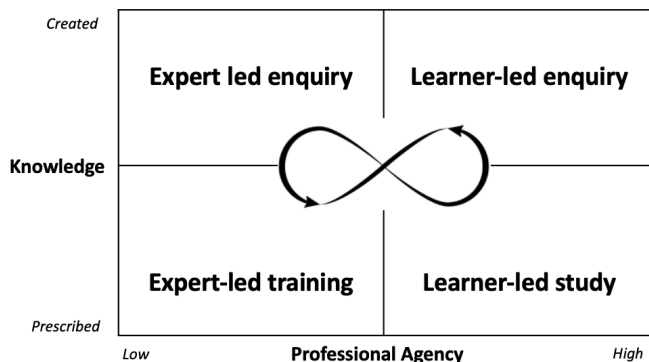

Fig. 2. Adapting the *Knowledge-Agency Window* for professional learning.

The lower-left quadrant represents learning about prescribed and existing knowledge, the domain of formal training led by experts where conceptual knowledge is typically acquired through a combination of content delivery exercises and then (one hopes) application in practice. There are typically right and wrong answers, and a formal test can assess the degree to which the learner has mastered that knowledge, at least when tested. In this quadrant, an adaptive AI tutorial might confront a professional with the diagnosis that they understand rather less than they thought about the fundamentals of a fast-moving topic, provoking reflection on the need to attend more to developments — or possibly, a reframing on whether this should still be part of their identity going forward.

In the lower-right quadrant, the professional learner is exercising more agency as they study to master a target skill, capability, or knowledge unit through an active choice, adapting that learning to their context.

In the top-left quadrant, we move into forms of "open ended enquiry" with no pre-defined curriculum to be mastered, through the generation and application of new knowledge led by experts. This might occur when a consultant leads an organisation through a change process, or a facilitator helps staff to generate new ideas. Depending on how effectively this is done, this may well introduce innovations into the organization, but a risk is that when the consultancy has finished and the expert departs, the organisation has failed to absorb that learning and built capacity in its own staff and practices, who revert to 'business as usual'. To overcome this problem, there is a need to combine individual learning with organisational learning in a 'double loop' process [29].

Finally, in the top-right quadrant, professionals are learning

together through the process of generating and applying new knowledge in their different contexts. This entails far greater levels of agency and complex problem-solving capabilities. Leadership development, for instance, requires a more agentic approach through trial and error in real work settings.

The cyclical arrows signal that professional learning can profitably occur in any of these four quadrants, but will increasingly integrate all four [30] since professional life presents increasingly novel challenges, for which there are no known solutions. Each of these four kinds of learning could provoke levels of reframing oneself, and clearly make very different demands on professionals. In particular, professionals need to be increasingly effective in the two right-hand quadrants, developing their self-leadership and that of their teams, all aligned to their organisational mission.

It has subsequently come to our attention that Ley [31] foregrounds the importance of learner agency in his framework for understanding the role of learning technology in the workplace. The overarching *guidance/emergence* continuum echoes the KAW's diagonal move (Fig. 1) from the lower-left to top-right quadrant. The convergence of these two independent research programs on similar constructs adds confidence that they have identified important qualities. Echoing Ley's analysis, in the next section we show how the KAW helps position the diverse contributions that learning technologies can make, but with specific interest in learning analytics.

IV. LEARNING TECHNOLOGIES/ANALYTICS VIEWED THROUGH THE KNOWLEDGE AGENCY WINDOW

A wide array of technology has been developed to support learners, and much of it has been adapted from formal education to the professional learning context. For example, many workplaces now utilize a learning management system (LMS) or comparable training platform, for content delivery, online assessment and progress tracking. This often includes compliance-based training to satisfy regulatory requirements (e.g., Occupational Health and Safety, Discrimination, and Supervision). Such training tends to focus on content mastery and provides little or no learner agency in determining the goals, assessments, and so forth. For this reason, we locate it in the lower-left quadrant of the KAW. There are clear criteria on what it means to start, finish, and pass/fail a learning activity, so to the degree that this resembles the way universities use such platforms for teaching, the armoury of LA (and now AI) techniques to enable the most efficient path to curriculum mastery may transfer well.

More progressive organisations are now embracing Learner Experience Platforms (LXPs) which provide the professional learner with more autonomy in choosing what they learn from an organizationally defined library of content (which can be very large), often providing recommendation systems to support learners in locating the content they require and defining a training path. These systems would be situated a little more to the right on the learner autonomy scale in the KAW, but since most tend to focus on content mastery, we still locate them in the lower-left quadrant.

Learning in this quadrant leaves unresolved Guile's 'recontextualisation' challenge introduced above [18], and leaves unaddressed the other quadrants in the KAW. To see this in action, more open-ended form of knowledge creation can be found in the various social media /networking platforms that are widely used by professionals (e.g., Teams; Twitter; LinkedIn; Facebook; YouTube; Reddit; Stack Exchange). These are sometimes used for formal directed learning (e.g., some schools and universities are starting to make use of Teams to teach their students rather than an LMS) but are more commonly facilitating technology for agentic and self-directed professional learning [32], [33]. Thus, a software engineer grappling with a new programming language can search Stack Exchange to find solutions to problems or ask a question which can be answered by more expert users in the community. These tools support the growth of extensive and open-ended professional learning networks, where experts help people to solve immediate problems, and so we locate them in the top-left quadrant of the KAW.

What contributions do LA have to make to professional learning when we situate it using the KAW lens? Dawson, et al. [34] argue that there is a need to understand "how and why the needs of workplace learners differ from formal students" (p. 3) in order to test theory and methods in authentic workplace settings. However, despite this acknowledged importance, a 2019 survey of LA research by Dawson, *et al.* [35], concluded that there was weak evidence from workplace learning contexts, suggesting the need for far more research in this space.

Since then, substantial overviews of the professional learning space have started to emerge. For example, a 2020 review of the forms of analytics delivered by professional learning environments was completed by Ng and Poquet [36]. They explored 80 digital solutions aiming to support professional learning, finding that the vast majority of analytics delivered were in the form of the Human Resource (HR) analytics, designed for managers, not the employees doing the learning, thus providing no direct autonomy to the professional learners. LXPs and LMSs provided analytics in the form of dashboards and reports, but it was found that the evidence for the effectiveness of these analytics was weak. On a more positive note, this analysis found that almost all of these tools had *some* descriptive analytics aiming to provoke reflection, but offered very little support for building learner agency, or interest-driven skills development. This is an ongoing weakness in the field that has been recognized by other researchers.

The most comprehensive examination of LA delivered by professional learning environments is provided by two systematic literature reviews of workplace learning analytics carried out by the same team. Ruiz-Calleja et al. conducted their first study in 2017 [37], replicating the methodology in 2021 [2], finding that the initial 30 papers on the topic had almost doubled to 52, signaling substantial growth in the field. Of particular interest to this paper, is their classification of approaches in the literature according to three different metaphors, which can be mapped into the KAW as suggested

by the regions in Fig. 3: (i) the *knowledge-acquisition metaphor* (22 papers were classified in this theme), focusing on individual learners mastering pre-defined concepts, which we map into the KAW as primarily lower-left, though with more effective learners likely pursuing their own efforts to research topics they have been assigned; (ii) the *participation metaphor* (19 papers), where social learning takes place through networks/ communities of practice, which in the KAW could harness learner, peer and expert input to define problems and solutions; and (iii) the *knowledge creation metaphor* (11 papers), which is concerned with the collaborative creation of new materials and conceptual artefacts in an organization, which we interpret in the KAW as drawing on similar modes to the participation metaphor.

Significantly, the authors note that relatively few approaches address the *knowledge creation* metaphor, identifying this as a key area for future work (KAW upper-right quadrant), and conclude that a key enabling factor for workplace LA is the degree to which *reflection* is part of a professional culture (e.g., as in education and healthcare), in contrast to others where this is more alien (e.g., manufacturing and construction).

The KAW framing of the literature clarifies the coverage of the different metaphors, enabling us to more specifically locate the approach being used against the learner agency dimension which we consider particularly important. This is a point to which we will turn next, when we introduce the need for more effective scaffolding of agentic reflection about one's identity as a learning professional, and the kind of LA approaches that seem to best fit this task.

V. IDENTITY, AGENCY, AND LA FOR REFRAMING ONESELF

Within educational research, the importance of how learners frame their identity is well established. Identity and agency are related in so far as they are both contextual and temporal, with identity looking backwards, and agency looking forwards to the achievement of a purpose. These have been described as the lateral and temporal connectivities which shape a person's sense of Self, particularly personal and communal stories, and networks of relationships [38], [39]. Sfard and Prusak [40] propose that the notion of identity is the 'missing link' between learning and its socio-cultural context. They frame identity as stories – reifying, endorsable by others and significant and profoundly influenced by others. Lave and Wenger refer to schooling as the construction of identities ([41], p.53), with other work focusing on the longer-term agenda of identity building [42].

To summarise, while formal educational systems clearly cultivate different identities to those encouraged in the workplace, and often remove rather than build learner agency, the theories and evidence in this literature demonstrate how central these qualities are to learners, and there is no reason to suppose that this ceases when they enter the workplace. Indeed, Dahlgren argues that "becoming a professional is a lifelong, extended process that constructs an individual's professional identity through formal education, workplace interactions and popular culture" [43].
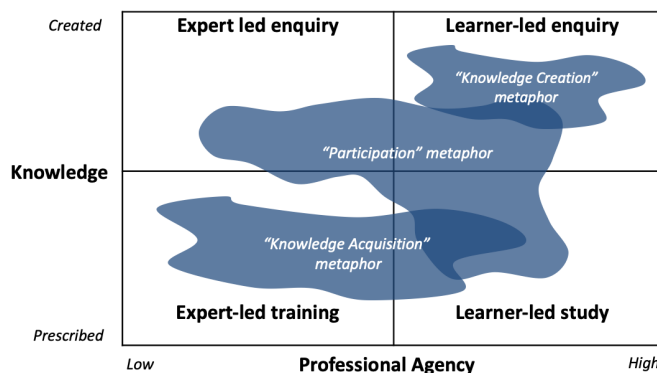

Fig. 3. Mapping the analysis of professional learning analytics literature by Ruiz-Calleja, *et al.* [2] into the *Knowledge-Agency Window*.

The centrality of identity, coupled with learner agency, indicates why the formation and re-formation of the professional self is so important. We propose, therefore, that the concept of *reframing oneself* encapsulates a particularly important kind of 'right-side' (in the KAW) agentic professional learning. Our interest is in whether LA-enabled technologies can help professionals gain insight into, and reflect on, their identity with a view to change. This is fundamentally concerned with making conscious decisions to change how one thinks and acts. We need to ask how LA can be used to scaffold *metacognitive* processes, such as planning, self-efficacy, self-leadership, learning relationships and persistence, in professional learning that stretches *outside* the prescribed boundaries of a formal course, or 'business as usual'.

In a straightforward, mundane sense, we can see the need to 'reframe oneself' on becoming aware of a personal shortcoming. Either privately or publicly, it becomes clear that one's confidence and/or competence to undertake a task is not as strong as it could or should be, covering the entire spectrum from learning a new technical skill or new regulations, to improving one's personal time-management, or interpersonal skills. The professional can choose to cover this up, ignore it, or address it proactively — a choice which may itself be a complex decision, charged with professional implications.

Beyond this, at a deeper level, 'reframing oneself' might connect to a more profound change in how one construes one's professional identity. Senior leadership development programs seek to instill a particular set of values and dispositions that go to the heart of one's identity (e.g., cultivating a spirit of *servant leadership*). Psychometric techniques, when used effectively, can provide new ways of thinking about oneself (e.g., realizing that you are a *Type X personality*, or holding certain *unconscious biases*). Reframing oneself may thus be incremental or transformative but is of course hardly a novel concept; counselling and psychotherapy often help patients 'reframe' themselves, as part of reconstructing their identities following trauma.

The LA examples that we introduce next are not based on employees' activity trace data (cf. research into LA inspired by self-regulation theory, which aggregates trace events from a formal learning platform, whether in an educational or workplace context [44], [45]. Employees already know that

enterprise systems log data describing their interactions. But this raises a key question of whether trust will be eroded if workplace analytics are used to draw erroneous conclusions about employees' professional capabilities, by treating low-level clicks as (impoverished) proxies for meaningful constructs. While learner activity-tracking is acceptable within the well-defined boundary of learning platforms delivering training, or reflective learning apps [46], the aggregation of trace data across diverse enterprise platforms in order to infer staff capabilities is, in our view, many orders of magnitude more complex, and correspondingly vulnerable to ethical concerns (for recent discussion on mitigating these risks in the workplace, see [47]).

We focus instead on approaches that seek to mitigate these risks in two ways. Firstly, the analytics operate on data explicitly shared by the professional as part of their intentional learning, not 'data exhaust' generated as a by-product of their work. A similar ethos was adopted by Schreurs & De Laat [48] in the design of a tool for teachers to reflect on their professional learning networks. Instead of deriving social network visualisations and metrics from social ties mined from an online platform (as is common in social learning analytics [49]), the teachers *manually* specified those colleagues whom they consulted about different topics, from which visualisations and reports were derived. Abstracting from this approach, we can see that this gave the benefits of *privacy* (teachers chose who to declare as peers), *coverage* (the network included both online and offline social ties) and *meaning* (teachers specified the topics they discussed). These attributes are important ones that we carry into our work, granting significant agency to the professional to manage what is shared, and what it means.

Secondly, we focus in this paper on natural language, with two of the LA approaches utilizing NLP. Written form can express extraordinary complexity and nuance, the challenge of stepping back and reflecting is well suited to the written word. As will be demonstrated, the machine reflects back to the learner the sense it can make of what has been shared, using both textual reports and visual annotation. (In the discussion we consider extensions to multimodal LA.)

Turning then to the design challenge, in what practical ways can analytics-enabled tools assist professionals in reframing themselves as learners? We next introduce three examples to illustrate the kinds of analytics that we are developing to provoke the construction of new self-narratives, exercising different forms of self-leadership. The idea is that once the professional is provided with new language (and hence, concepts) with which to think, they can more clearly narrate their journey, to themselves and possibly to others.

- **Skills Analytics:** How do I tell my "skills story" to myself, and to others, as I seek to pivot and maintain relevance in this turbulent organisation? Where am I on my career trajectory? What skills should I aspire to acquire?
- **Reflective Writing Analytics:** How can I make sense of this challenging experience? How could I handle such dilemmas better next time? What am I still uncertain about? How am I changing as a professional?

- **Dispositional Analytics:** What is my professional purpose? What does it mean to get better at 'learning to learn'? How can I use my next project to stretch myself, beyond just getting the job done? How can I transfer what I have learned in formal education and training and apply this knowledge to my job?

The three examples are mapped into the KAW in Fig. 4. In each case, the tool is designed to help the learner see and understand themselves in a new way. Through automated, personalized feedback they are then provided with suggestions for how they might reflect and respond.

We recognise the complex ethics issues related to data analysis in work contexts which are beyond the scope of this paper. However, as we introduce the approaches in detail, each section concludes with a consideration of their ethical usage in professional contexts.
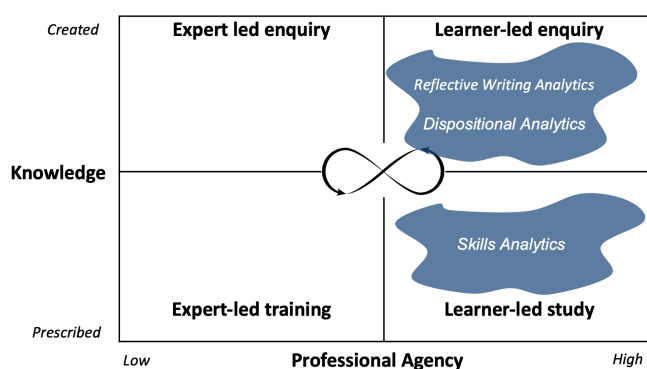

Fig. 4. Locating the three examples of professional learning analytics approaches discussed in this paper within the Knowledge-Agency Window.

VI. Skills Analytics

As discussed above, professional learners often need to learn a set of new skills on the job, flexibly, and as required. They might sometimes do this via formal training pathways, but this leaves them with the problem of transferring the knowledge they learned in the (physical or online) classroom to the work context [20]. Often, we see professional learners following less well-defined methods, working to self-identify gaps in their capabilities, reflect upon which gaps are most detrimental to their performance, and then work to find resources that might help them to improve upon their skill base in key targeted areas.

However, many people find it difficult to articulate the skills that they acquire [20], a problem that is often seen in job interviews and responses to selection criteria. While many employers report a gap between the skills that they are looking for and those of people who apply for their jobs, it has been argued that this is largely due to a lack of awareness, or a failure of graduates to articulate the skills that they have gained during their education [50]. We need ways to support people in organisations and articulating the skills that they possess [20]. Furthermore, it is often difficult for learners to identify new skills and capabilities that are likely to provide the best return on investment; should they prioritise novel skills that complement existing skills in their team, focus on new emerging skills, or aim to maintain relevance by working to achieve the standard competencies possessed by their

colleagues? These questions are particularly challenging in agile workplaces where team composition changes rapidly.

The need for skills analytics in the workplace has been well recognized by the private sector, and particularly within the human resources (HR) training space, where a wide variety of solutions are now being aggressively developed and pursued by companies such as *Microsoft, LinkedIn, Emsi/Burning Glass* and *Cornerstone on Demand* which seek to support the tracking of skills demonstrated by a professional. The result is usually technological solutions of varying levels of sophistication, that aim to support people in explicitly claiming skills, identifying possible skill gaps, and then using these insights to target training that might serve to support them in working towards career goals.

This class of tools tends to rely upon a predefined skills vocabulary, which links occupations to the skills required in that occupation. Some of these are curated by hand, including the *Occupational Information Network (O*NET)* [51] and *European Skill/ Competences, qualifications and Occupations (ESCO)* [52] framework, but increasingly these skills vocabularies are created by applying Natural Language Processing (NLP) to extract skills, locations, and salary information from large online job advertisement databases. Humans then often provide oversight to add commonly occurring skills to the vocabulary. The resulting curated data is then sold to government bodies, companies, institutions, and educational providers to provide services that expedite the Recognition of Prior Learning [53] and curriculum profiling [54] in terms of defined skills taxonomies.. This data can also be used to support professional learning, from both a top-down employer centric perspective to track employee skills and capabilities, but also from a more emergent and learner centered perspective where professional learners chart a course towards identified career goals and new opportunities. It is this second scenario that opens up the possibility of using skills analytics for reframing oneself.

Professionals increasingly need to perform this reframing, as they face change in an existing position and need to update their skillsets in response to technological change, or perhaps even change position to a new role, or indeed move organisations. Thus, in supporting professional learners to upskill we need systems that balance the skills needs of their current organization with projected needs in their future careers. In short, professionals need to be able to set and attain learning goals that not only benefit their current organisation, but also allow each individual opportunity to navigate their own career pathway. This approach to career support has been termed 'Charting' [20], where professionals set their learning goals, and then source, use, adapt and share knowledge resources in ways that help them attain these goals. Charting provides a bottom-up approach to professional learning, but it can be difficult for professionals to articulate their career goals, a topic to which we return in the discussion.

In Fig. 5 we depict a prototype tool now being piloted at the University of Technology Sydney (UTS), which helps people reframe themselves by explicitly listing their professional goals, and then identifying learning pathways that might help

them to achieve those goals. The TRACK (Tailored Recruitment and Curriculum Knowledge) web app helps people to consider their current capabilities by creating a *skills profile* (Fig. 5, *top*). The user starts by actively identify skills that they currently have, either by uploading a CV which is parsed using NLP, searching for occupation names for jobs they have held in the past, or searching for specific skills on a case-by-case basis. This explicit claiming of skills encourages a professional learner to reflect upon their existing skills and capabilities, and these can be represented according to organizational needs (e.g., using capability frameworks that map the skills), or kept more open (e.g., using all skills available in the tool). This skills profile can then be used to set career goals, and identify gaps in their profile with respect to those goals. This enables the professional learner to explore alternative career goals, and to investigate how their current skills mix interacts with those goals to make different outcomes more or less difficult to achieve. Finally, the tool helps the learner to find training opportunities at UTS that could fill a critical skills gap (Fig. 5, *bottom*). This is possible because the courses at UTS are tagged using NLP with skills from the same taxonomy as the tool itself. While this tool links skills gaps to curriculum offerings within a specific institution [55], the *eDoer* tool [56] is a prototype recommendation system that suggests open educational resources based upon a similar skills analytics approach [57].

Maturity level. TRACK, and similar tools using NLP to analyse labour market data, have emerged as widely available services in only the last five years approximately, and are the subject of significant commercial investment to improve skills extraction, clustering, similarity matching and recommender systems. Looking to the future, the learner profile that is generated could in principle be used over a lifetime, beyond the boundaries of the organisation for which it was first created. This could enable reframing of oneself over a lifetime, through the active and deliberate claiming of skills, setting of career goals, and the identification of skills gaps which training opportunities can help to fill. In the future learners should also have the power to 'unframe' parts of their career they may want to forget [58]. For example, an individual going through a life crisis might take time out of their career, or begin a new career track. Later in life they may want to return to their original career pathway, so it may be helpful for them to amend their track record to suit their new pathway. This form of 'forgetting' can be important for people, particularly those who are marginalized and are therefore more likely to go through difficult periods throughout their lives.

Thus, it is possible to envisage a future where we move towards professional learners shaping and controlling their own profiles, rather than having this done for them by technical systems. Each professional can use this skills profile that they have created to understand their current professional context, and extend it to other scenarios, training and career goals which are situated beyond their current workplace. Extensions to this approach could include analytics that take the relative contribution of a skill into account. For example, Dawson et al. [59] describe a *Revealed Comparative Advantage* measure
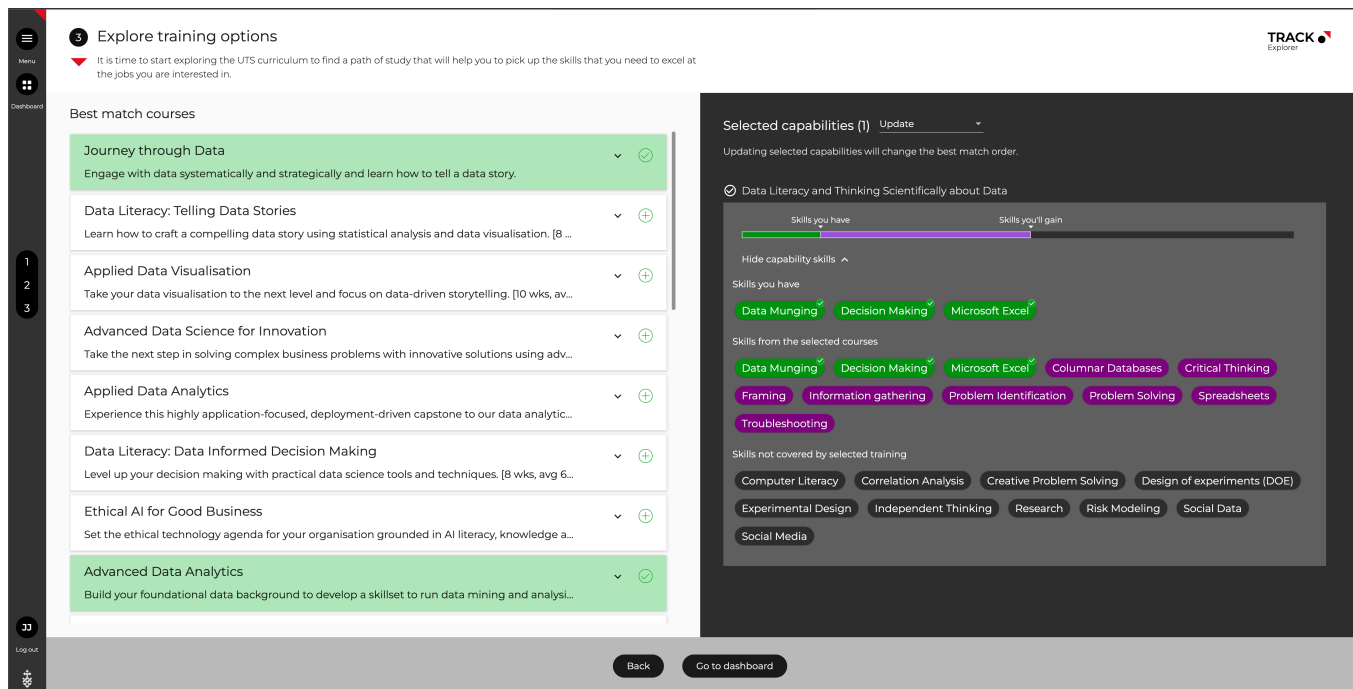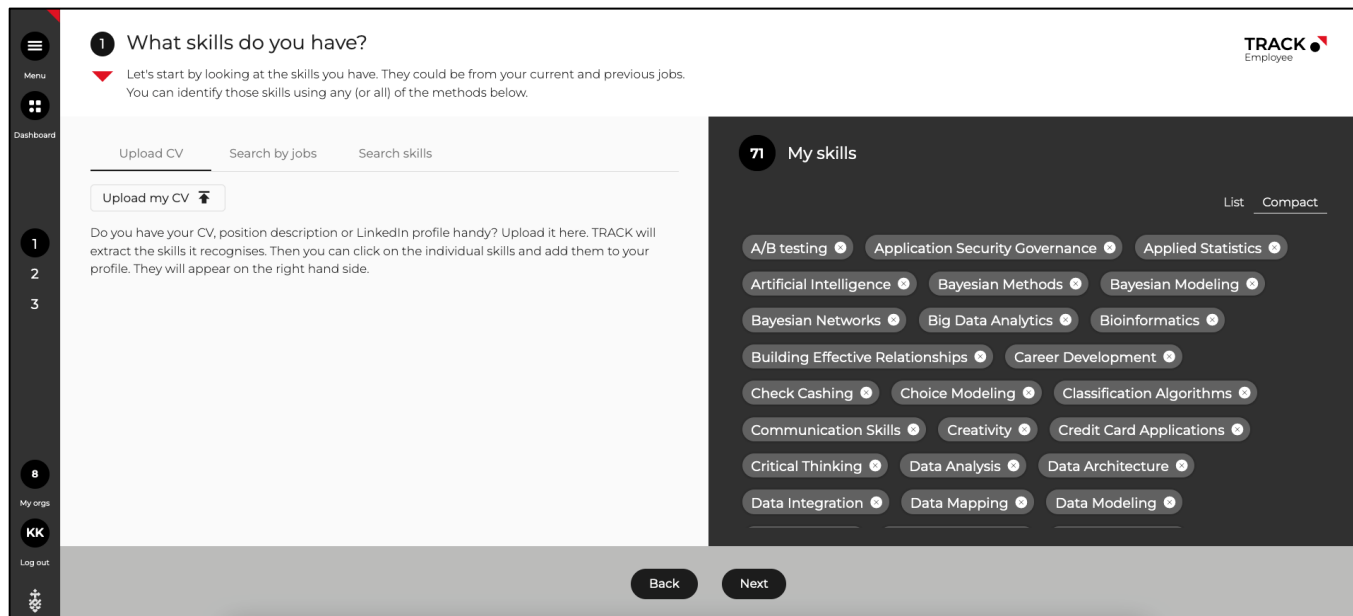
Fig. 5. TRACK: a suite of web applications to assist learners in reflecting on their current and potential future skills profile. Natural language processing services index skills from three sources: the learner's CV, course options and job advertisements, in order to calculate the degree of overlap, from which a recommendation engine suggests potential learning pathways. *(Top)*The learner is shown a list of skills extracted from their CV, for them to review and edit. Additional skills can be added by searching for jobs or specific skills. *(Bottom)* Based on the learner's career aspirations, and the skills they want to work on

which enables them to determine which skills are most likely to provide the largest advantage to a professional learner seeking to transition to a new role. When combined with data about job market trends, this approach has potential to provide professional learners with data and analytics approaches that support them in charting their learning trajectories over a lifetime, with intermediate career goals, planning short term goals as 'stepping stones' on the way to a longer-term objective [55].

Returning to the KAW, we classify these skills-based approaches as high in professional agency (as the learner is free to choose whichever learning opportunities are mapped in the tool), but as likely to be geared towards more prescribed knowledge (as existing tools do not tend to support the creation of new knowledge, rather the acquisition of existing knowledge). As such, it fills an important gap that we identified earlier, by helping professional learners to choose between prescribed training options to chart their way towards identified career goals.

Ethical considerations. We have proposed that tools such as TRACK, and the growing number of similar services, can be used to empower professionals to reflect on how they want to

change their expertise. Such tools are being marketed as part of 'workforce analytics' to help organisations track staff wellbeing and performance, and design their future workforces. There is certainly scope for such tools to be used in ways that staff could experience as stressful. For instance, in the context of potential job losses, the invitation to complete one's skills profile can be perceived as supportive (e.g., "this is proactive support to map your career trajectory, to give you the training you need for future roles") or threatening ("this tool will provide hard evidence that you no longer fit here"). The management culture will shape this, as will each employee's dispositions and competence. Like all analytics, such tools can bring a level of precision and fairness to decisions that until now have depended on weak evidence and human biases, but if people are reduced to only a quantifiable skills profile, to the exclusion of other important qualities for designing effective, rewarding workplaces, too much agency will have been surrendered to analytics.

VII. REFLECTIVE WRITING ANALYTICS

Reflecting on experiences is critical for professional learning. Transferring and applying the knowledge learned in one context to another is challenging and a major barrier to professionals as they learn. Work can be bruising emotionally, and the stakes for failure can be high socially, financially, politically. What contributions can analytics possibly make to such a complex cognitive, social and emotional process?

Let us start with how humans assist reflection. Helping people make sense of their thoughts, feelings, reactions and approaches when stretched out of their comfort zones is core business for leadership coaches. Suitably supported, honest reflection makes it safe to question assumptions and consider change, but we also know that this is often both difficult to teach and challenging to learn. Professional coaches can be brought in to support this process for individuals and teams [60], but while we know there is nothing as valuable as detailed coaching feedback to build this capacity, this is a scarce, costly skillset and labour-intensive.

It is in this regard that learning technology using analytics, and now AI, may have a contribution to make if they can help professionals to reflect on the situations/people they find most challenging. While there are various ways to express one's thoughts and feelings, when we look at current practice in both education and professional development, *writing* is the most widely used modality, offering for both the authors, and others if they share their reflections, a 'window' onto the mind. As any dedicated writer will attest, the *act of writing* is a mirror helping to clarify what one really thinks.

Reflective writing (e.g., through a learning journal) is an approach used in many professions to help learners, professionals and leaders make sense of challenging experiences, and prepare for the future. It integrates "head and heart", valuing not only technical/academic knowledge, but how this interacts with experiential/professional ways of

Fig. 6. Two tabs from the AcaWriter web application providing automated feedback on a paragraph of professional reflective writing. *(Left)* The first tab uses icons and typography (see legend) to semantically annotate sentences where the writer appears to be engaging in deeper reflection. *(Right)* The second tab provides personalised feedback messages.

knowing, and recognising the fact that learning and working engage our emotions and feelings. In sharp contrast to conventional academic, business or technical analysis, the focus in such writing is not on persuading the reader or demonstrating mastery of a topic. In reflective writing, one writes in the first person, often for oneself rather than an audience, typically describing *critical incidents* that were *surprising or challenging*, the *thoughts, beliefs, feelings* and *emotions* these evoked, and how one is *changing* as a result, for instance, to better handle similar situations when they next arise.

Our work to date has developed a web app called AcaWriter using natural language processing to detect the presence of textual features that signal a range of hallmark 'rhetorical moves' in reflection (as italicised above). In principle, this opens the possibility for offering instant, personalised feedback on personal reflections about challenging experiences, at scale. We have detailed how scholarship into the teaching and learning of reflective writing provides key insights into the hallmarks of effective reflection, and reflective writing ([61], [62]). Since the purpose of reflective writing is to honestly externalise one's thoughts in order to make sense of challenging experiences, the analytics are not intended to be summative grading of a 'performance', but to provoke deeper reflection.

AcaWriter has demonstrated its value in vocationally-focused higher education courses where trainees reflect on work placement experiences (e.g. Pharmacy [63]) and challenging new courses (e.g., Gender Studies [61]). To our knowledge, this kind of tool has yet to be used by professionals in the workplace, but we are receiving expressions of interest from professional bodies who use reflective writing as part of staff development. An indicator that the underlying model could generalise to the kinds of reflection that employees/leaders is illustrated in Fig. 6, showing that AcaWriter can to a degree appropriately classify sentences and give feedback on leadership reflective writing (an example from [60]), but clearly, more systematic evaluation is required. Further work could improve the classifier's performance (e.g. through supervised machine learning, as demonstrated for trainee pharmacists' reflections [64]), enabling us to gather empirical evidence of the response it gets from professionals. Automated feedback such as this cannot replace the holistic, multifaceted workplace mentoring provided by human mentors, but could complement it. For instance, the availability of 24/7 feedback (which no human can provide) could prompt professionals to revise and advance their thinking and writing more extensively prior to discussing with a mentor.

Maturity level. There is a growing number of commercial products on the market providing automated writing feedback beyond spelling and grammar checking, to address the particular emphasis on ideas that one finds in scholarly/scientific writing. However, to our knowledge, AcaWriter is the first tool providing automated *feedback* on *reflective* writing, although other parsers have been developed by researchers studying reflective writing [65]–[68]. The possibility for learning technologies to recognise and give feedback on such writing places this example firmly in the KAW right-side quadrants, but of the three examples we

discuss, this is the least tested in professional learning contexts. Future work should investigate performance on different kinds of professional reflective writing, and explore the potential of machine learning, which has demonstrated potential in reflective writing [64], [69]. Such tools should be carefully piloted in workplaces, ideally as an integrated part of leadership development programs, and may find adoption most quickly in professions already familiar with this form of reflective practice, such as teaching, nursing, medicine or pharmacy.

Ethical considerations. Reflective writing is a personal, private activity, which is shared by the author through choice. It is not mandatory, and the learner can choose not to contribute. Nevertheless, organisations that encourage reflective writing must build employee trust by providing safeguards around the storage of resources and data, as well as access to reflective writing analytics. The trend to procuring cloud services from external vendors offers one approach that enables employee access to the writing feedback with technical safeguards, for example preventing managers' access (other than seeing summary statistics regarding the levels of usage of the service). In this way organisations can ethically design opportunities for employees to share their reflections and insights in ways that improve professional and organisational learning.

VIII. Dispositional Learning Analytics

"Knowledge of methods alone will not suffice: there must be the desire, the will, to employ them. This desire is an affair of personal disposition." Dewey, 1933 [70]
"A disposition is a tendency to exhibit frequently, consciously, and voluntarily a pattern of behavior that is directed to a broad goal." Katz, 1993 [71]

As Katz defines it, a disposition is a habit of both mind and action, a *tendency to behave* in a certain way, while Dewey emphasises the pivotal role of *desire/will* to act. We argue that the term 'disposition' should not be reduced to solely how someone tends to behave (which is observable and thus measurable) but that dispositions emerge out of a particular narrative which is both historical and future-oriented, as well as situated and contextual (making it more challenging for measurement). What is being addressed is a set of personal qualities or orientations towards learning which are understood and manifested in thought, feeling and action, and derive from values and attitudes — sets of beliefs with affective loading. The concept of 'learning power' (introduced below) is a broader term for this because it incorporates values, attitudes and dispositions, and in addition invokes the important concept of agency, purpose and self-leadership [72]–[74].

Dispositional Learning Analytics (DLA) is a term used to describe feedback of data returned to a learner, designed to inform them about their learning dispositions, so that they can use that information to increase and develop self-awareness, ownership and responsibility for their own learning trajectories [75]. It has made an impact in primary [76]–[78], secondary [79]–[83] and tertiary educational contexts [1], [84]–[85]. DLA

can also be used to provide *coaches/educators* with insights into their cohort and *researchers* with insights into learning processes, as well as the characteristics of different groups. In the latter case, DLA has been shown to provide a statistically significant source of explanatory power when predicting student performance, and in designing more personalised feedback [86]–[87].

The example of DLA which we have been developing has focused on feedback to the learner after using a self-report diagnostic survey. The CLARA survey assesses *Learning Power*, defined as 'the embodied and relational process through which we regulate the flow of energy and information over time in order to navigate a learning journey to achieve a purpose of value' [3] (p.121). The survey has been validated as a set of eight scales measuring the latent variables of *Mindful Agency, Sense Making, Creativity, Curiosity, Belonging, Collaboration, Hope and Optimism* and *Openness to Learning* (Fig. 7). These dimensions measure dispositions (what one tends to do), affect (feelings) and beliefs (cognition) about a a learner's typical response to learning in a given context.

Embedded in a web application called WILD (Work-Integrated Learning Design), the tool provides visual feedback (Fig. 8) and a personalised feedback report for personal reflection or a coaching conversation. A useful metaphor for this cycle is a work-integrated 'learning journey', whereby the app invites the learner to reflect on the purpose of this exercise, and how they can reframe themselves and their job in the light of the learning power dimensions they want to work on. The power of the metaphor is that it foregrounds the agency of the person who is taking the journey and the 'territory' over which the journey proceeds: both are core to professional learning. The platform [88] also provides aggregate learning power statistics at the team and organisational levels, to aid leadership decision making, but if staff want, their identities can be hidden to ensure that what is intended to be formative feedback is not distorted into a high-stakes performance assessment that managers can use.

This approach of undertaking a learning journey, scaffolded by reflection on learning power, has been developed particularly with self-directed learning in mind, both individual or in a team. It is defined by the situated nature of the problem itself, the purposes of the stakeholders, and the possible solutions in that context. In contrast to the left-side of the KAW, the professional engages with prescribed or expert-guided funds of knowledge *after* they have begun to explore the problem space. The onus is on the individual themselves to then identify, collect and curate the data and knowledge they need. This capacity for identifying, collecting, curating and working with sources locates this example in the top-right quadrant.

Maturity level. As the longest-standing of the three examples in this paper, in development for over a decade, this DLA approach has been adapted from its formal education origins in middle/high schools, and introduced as part of project work and work-integrated learning in higher education [89], and most recently, deployed in leadership development and work-integrated learning strategy in a public utility, engaging over 100 executives and leaders for three years, with positive

Mindful Agency... Seeing the big picture, taking responsibility and being proactive, while managing my feelings; the opposite is being 'robotic'.

Sense Making... Making connections between ideas, memories, facts – everything you know – linking them and seeing patterns and meaning. Its about how learning matters to you.

Creativity... Risk-taking, playfulness, using my imagination and intuition in my learning; the opposite is being 'rule-bound'.

Curiosity... Asking questions, wanting to know more, getting below the surface, refusing to take things at face value; the opposite is passivity.

Belonging... Being supported, encouraged, feeling at home, in my learning community; the opposite is being 'out of place'.

Collaboration... Interacting with fellow learners, getting and giving support, solving problems by teamwork; the opposite is being isolated.

Hope & Optimism... Seeing myself as one who learns, grows, improves over time, having travelled already; the opposite is being 'stuck and static'.

Orientation to Learning... Being ready and open: striking a balance between determination and adaptability; not too fragile and dependent nor too rigid and persistent.

Fig. 7. The "Learning Power" construct has eight dimensions that together define a quality of learners termed "resilient agency" [3].
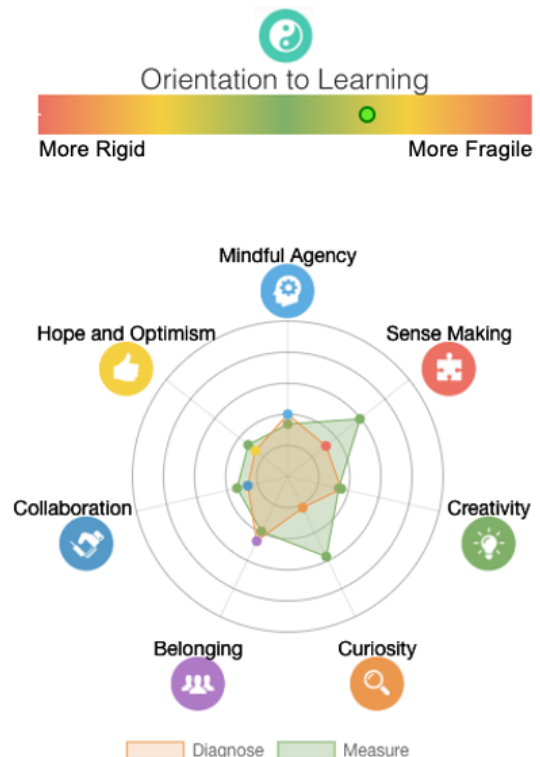
Fig. 8. Visual analytic feedback to the learner on completion of the diagnostic survey. This example shows changes (from *Diagnose* to *Measure*) following a learner-defined work-integrated learning journey, scaffolded by the WILD web application.

outcomes [90]–[91]. Future research now under consideration, which could help to scale the approach in the absence of skilled human coaches, includes the possibility of adding an AI coaching agent to provoke dialogic reflection about the potential implications of one's profile. One can also envisage 'theming' the currently generic reports with locally contextualised language, iconography and case examples.

Ethical considerations. The ethical implications of DLA arise from the personal and unique nature of an individual's sense of identity as a learner, which emerges from their particular story, and is projected into their future aspirations. The learner's task is to first make sense of their DLA report which presents visual data based on reliable, research validated, numerical scales. Next, they use this data to deepen their own self-awareness, asking and answering questions such as 'why am I like this' and 'what might I want to change'. Ideally, they also have access to a coaching conversation to support the process and help to convert their self-awareness into strategies for change. The purpose of the rapid feedback of DLA is formative and ipsative, designed to inform a (self) coaching conversation that stimulates self-awareness, and agency in learning. This personal process of interpretation leading to action draws on interpretive and emancipatory rationality and raises ethical issues like those which apply to coaching relationships[2]. In other words, the emergent outcomes of DLA can be deeply personal, and impact the learner in significant ways. The first ethical issue therefore relates to research quality, reliability and trustworthiness. The data used to build the visual feedback should meet the robust standards of social science.

The second ethical issue relates to privacy. If the DLA data architecture is designed in a way that enables other people in the system to see and read Learning Power data without the explicit permission of the learner, then this will have an immediate negative impact on (i) quality and (ii) learner wellbeing. Quality, because once the data is used for judging and performance-oriented decisions, it will lead to 'gaming' and will actually have the opposite effect from what was intended (i.e. performativity); wellbeing, because the use of such personal data for performance management and assessment will impact on learner's self-esteem, self-efficacy and effort [92]. The privacy of the individual data set is paramount, the manner in which it is made available to the individual is an ethical issue, as is the use to which the data is put by the institution concerned, in terms of leadership decision making. The key ethical principles are 'fitness for purpose' and the authority of the individual learner. As with reflective writing analytics, the terms on which a responsible DLA service provider operates must safeguard these requirements, managed via suitable data models, role permissions and policies.

IX. DISCUSSION

This paper has focused on the question of whether, and in what forms, Learning Analytics (LA) can enable work-integrated, professional learning. We have argued that the different forms of professional learning are clarified by the adapted version of the Knowledge-Agency Window (KAW) (Fig. 2). The KAW clarifies the centrality of agency and identity in professional learning, and its dimensions offer a design space to compare and contrast different learning technologies and LA approaches (Figs. 3-4). LA approaches developed in formal educational contexts typically analyse learner activity data from learning platforms and may translate partially to formal professional development (KAW lower-left quadrant). However, the deeper challenge is to design LA for work-integrated professional learning, which is vital for the continual improvement of work in organisations. The KAW framework demonstrates that to support work-integrated professional learning, the primary challenge is to invent and validate LA for learner-led enquiry and learner-led study (the right-side quadrants in Fig 2).

We have argued that LA can support professionals in becoming more agentic learners by reconfiguring and reflecting back *data they intentionally share* as feedback, to help *"reframe oneself"*. This reframing may be incremental or more transformative. To ground this concept, we have presented three examples of LA approaches that share this perspective in common, all of which are implemented as web applications. These illustrate how this perspective can be translated in diverse ways. We have contrasted this to LA approaches that analyse activity traces, since in the context of the enterprise platforms used by professionals in their everyday work (as opposed to completing a formal, bounded training module), this breadth of surveillance introduces both ethical concerns, as well as complex data-modelling challenges, namely, how to infer higher order professional competencies from low-level activity logs.

In the remainder of this paper, we discuss some defining features of this proposal, and further implications.

A. The centrality of professional agency

Agency is a core human process in a learning infrastructure which enhances organisational adaptive capacity. Agency is the capacity for self-leadership in achieving a purpose, which, in the workplace, generally means finding solutions to complex problems the answers to which are not known in advance (in contrast to most formal learning). It involves the ways in which the professional analyses and responds to challenges by identifying the knowledge, skills, know-how and data which they need to re-construct, in order to find solutions which are fit for purpose. As suggested in an international survey of HR trends [93], the workforce of the future needs to be able to follow a 'playbook' not a 'rulebook' — following a playbook requires a sense of purpose, agency and resourcefulness for self-directed learning. Professional agency goes beyond merely the personal: by definition it is the agency of a professional, in a particular profession, in a particular context. It is multi-levelled in the sense professional agency is expressed through purpose in an organisation as a complex system — a

---

professional's personal purpose is aligned with the purpose of their profession, which is expressed organisationally through their workplace [94].

The implications of this for Learning Analytics are significant. LA to augment agency should be designed around the individual's capacity for sensemaking, for self-reflection, for coaching-for-learning relationships, and for thinking skills which enable the professional to generate new knowledge to solve contextual, new problems. LA for professional agency is about returning meaningful data to the professional (agent) so that they can make better informed decisions about themself, their skills or how they go about solving complex problems and generating new knowledge.

As discussed in the ethical reflections on each of the three examples, there must be appropriate permissions around the level of detail in someone's data that managers and peers can see, in order to avoid undermining the honest, reflective processes that are being encouraged. An additional ethical consideration that we wish to highlight is the possibility that LA feedback such as this is unsettling and confronting for someone. On the one hand, we only learn when confronted with the fact that we fall short in some way, and we recognise the need to grow. Skilled educators know how to create a sense of disorientation but also curiosity in the learner, but learners will navigate this space if supported suitably. Taking the three exemplars: TRACK may confront learners with their skills gap, but offers pathways to tackle it; WILD may confront them with their dispositional profile but provides coaching feedback; and AcaWriter may confront them by failing to see any deep reflection in their writing, but provides visual and written prompts on making their thinking more visible.

B. LA-informed goal-setting as a way to build agency

We noted earlier prior work in which Littlejohn et al. investigated an approach called *Charting* which involves professionals in setting short, medium and long-term career goals [20]. However, one finding was that this task proved to be a challenge for many, so the question arises as to whether LA can provide support for this critical activity, which is central to the concept of agency. Two of the three examples require the learner to explore, and (at least tentatively) set goals, based on the analytics feedback. In the Skills Analytics example, TRACK requires the learner to explore jobs of interest in order to recommend courses that will close the skills gap. A corporate version invites employees to indicate their interest in new roles that the organisation has prioritised for their future workforce, in order to explore their skills fit. Goal-setting is an iterative process, informed by the feedback on skills matches, gaps and gains. In DLA, the WILD web app requires the learner to set personal and professional goals for improving their learning processes on a work-based project. The research-validated framework underpins the personalised feedback, which provides a foundation for reflection or coaching conversations explicitly focused on self-awareness and goal setting. Goals are informed by the shape and size of the radar chart visualisation, the feedback on this profile, and how it changes over time.

C. Multimodal LA through the KAW

In introducing our approach, we noted that the examples all focus on natural language, since this is one of the most intuitive modalities in which to reflect, express complex ideas, and craft narratives. We recognise, of course, that there are other modalities in which one might capture personal reflections, such as audio or video (AV) diaries/blogs, each of which introduces new possibilities for automated, formative analytics feedback. Speech-to-text conversion is now so good that content and rhetorical analysis of AV reflections is a commodity cloud service. Furthermore, despite the digital revolution many forms of professional work remain embodied in physical space, and typically collocated with colleagues. *Multimodal* LA (MMLA) [95] use sensors to detect attributes of embodied learning such as posture, physiological correlates of stress (e.g., via biometric wristbands), movement (e.g., via indoor location trackers), and communication (via speech and video analysis).

The KAW framework can be applied to frame the deployment of such approaches, for instance, MMLA feedback to trainees on how well they performed against the exacting standards of a teamwork simulation belongs in the *lower-left quadrant* [96], while formative feedback to educators on their movement around teaching spaces is *lower-right* since no judgement is made, and it is up to them what this might mean for improving their practice [97]. If employees choose to track their office movements as a memory aid or source of insight about work habits [98], we might locate this in the *top-right quadrant,* but if they are under duress to do so to assist 'organisational learning' about office usage, from a learner agency perspective this is clearly very different.

MMLA tools raise significant ethical issues since they are at least if not more invasive than online sensors, and relying on machines to interpret people's non-verbal behaviour is extremely challenging. MMLA ethics are a topic of debate (albeit largely in the context of formal education [99]), and as emphasised in our preceding ethical discussions, it must be very clear what data is being gathered, when, by whom, and for what purposes.

D. Limitations of this analysis

We recognise several limitations to this analysis which future work can address. Firstly, the nature of work is changing rapidly, and although the assumptions underpinning the KAW are intended to address this turbulence, we remain open to the possibility that the KAW may need to be revised. Secondly, technology is changing rapidly, and the KAW framework must be tested against the affordances of new learning infrastructures, which could in principle demonstrate the need to modify or add dimensions. Finally, the three LA tool examples we have presented are only just emerging as professional learning tools. We have argued that they are in principle well suited for use in the workplace. There is published evidence regarding the use of DLA in the workplace [90], and organizational trials are under way with Skills Analytics, but future research must establish more robust empirical evidence.

X. Conclusion

In the current turbulence confronting organisations, with the need for continuous, work-integrated professional learning, we believe that sustainable organisational learning and change will be driven 'from the inside out' through the agentic learning of their people. Professional Learning Analytics must expand beyond the current focus on formal training/education to build learner agency to navigate informal learning settings. Rather than LA reframing learning in the classroom, learners themselves must learn to reframe their learning needs and goals. This will entail at least four modes of learning as described in the adapted KAW framework, of which the agentic quadrants remain the least well understood when it comes to designing learning technologies. It is important that professionals have agency over their own data profiles, which amidst current concerns around the ethics of data, is another important step towards rebalancing equity issues, and is particularly important for marginalised people. We hope that this analysis provides both conceptual language and technical inspiration to align the computing sciences with the learning sciences in ethical ways, to help envision Professional Learning Analytics that respect these values, and advance the deeper learning associated with reframing oneself.

References

[1] P. Godfrey, R. D. Crick, and S. Huang, "Systems Thinking, Systems Design and Learning Power in Engineering Education," *Int. Jnl. of Engineering Education,* vol. 30, pp. 112–127, 2014.

[2] A. Ruiz-Calleja, L. P. P. Prieto, T. Ley, M. J. Rodriguez-Triana, and S. Dennerlein, "Learning Analytics for Professional and Workplace Learning: A Literature Review," *IEEE Transactions on Learning Technologies,* pp. 1-1, 2021, doi: 10.1109/TLT.2021.3092219.

[3] R. Deakin Crick, S. Huang, A. Ahmed-Shafi, and C. Goldspink, "Developing Resilient Agency in Learning: The Internal Structure of Learning Power," *British Jnl. of Educational Studies,* vol. 63, no. 2, pp. 121- 160, 2015, doi: 10.1080/00071005.2015.1006574.

[4] A. Littlejohn and A. Margaryan, "Technology-enhanced professional learning," in *Int. Handbook of Research in Professional and Practice-based Learning.* Dordrecht: Springer, 2014, pp. 1187-1212.

[5] P. Tynjälä, "Perspectives into learning at the workplace," *Educational Research Review,* vol. 3, no. 2, pp. 130-154, 2008.

[6] M. Eraut and W. Hirsh, *The significance of workplace learning for individuals, groups and organisations*. Oxford: Skope, 2010.

[7] M. Eraut, "Non-formal learning and tacit knowledge in professional work," *British Jnl. of Educational Psychology,* vol. 70, no. 1, pp. 113- 136, 2000.

[8] A. Littlejohn, C. Milligan, R. P. Fontana, and A. Margaryan, "Professional Learning Through Everyday Work: How Finance Professionals Self-Regulate Their Learning," *Vocations and Learning: Studies in Vocational and Professional Education,* vol. 9, pp. 207-226, 2016.

[9] C. Harteis and S. Billett, "The workplace as learning environment: Introduction," *Int. Jnl. of Educational Research,* vol. 47, no. 4, pp. 209-212, 2008.

[10] J. Derrick, "“Tacit pedagogy” and “entanglement”: practice-based learning and innovation," *Jnl. of Workplace Learning,* vol. 32, no. 4, pp. 273-284, 2020, doi: 10.1108/jwl-07-2019-0094.

[11] C. Lang, G. Siemens, A. F. Wise, and D. Gašević, Eds. *The Handbook of Learning Analytics (1st Ed.)*. Alberta, Canada: Society for Learning Analytics Research, 2017.

[12] C. Lang, G. Siemens, A. F. Wise, D. Gašević, and A. Merceron, Eds. *The Handbook of Learning Analytics (2nd Ed.)*. Alberta, Canada: Society for Learning Analytics Research, 2022.

[13] B. J. Zimmerman, "Attaining self-regulation: A social cognitive perspective," in *Handbook of Self-Regulation*, M. Boekaerts, M. Zeidner, and P. R. Pintrich Eds. San Diego, CA: Academic Press, 2000, pp. 13-39.

[14] P. R. Pintrich, "The role of goal orientation in self-regulated learning," in *Handbook of Self-Regulation*: Academic Press, 2000, pp. 451-502.

[15] A. Bandura, "The explanatory and predictive scope of self-efficacy theory," *Jnl. of Social and Clinical Psychology,* vol. 4, no. 3, pp. 359-373, 1986.

[16] P. H. Winne, "Inherent details in self-regulated learning," *Educational psychologist,* vol. 30, no. 4, pp. 173-187, 1995.

[17] T. Sitzmann and E. K., "A meta-analysis of self-regulated learning in work-related training and educational attainment: What we know and where we need to go," *Psychological Bulletin,* vol. 137, no. 3, pp. 421-442, 2011.

[18] D. Guile, "Professional knowledge and professional practice as continuous recontextualisation: A social practice perspective," in *Knowledge, expertise and the professions*: Routledge, 2014, pp. 88-102.

[19] S. Järvelä, J. Malmberg, E. Haataja, M. Sobocinski, and P. A. Kirschner, "What multimodal data can tell us about the students' regulation of their learning process?," *Learning and Instruction,* vol. 72, p. 101203, 2021, doi: 10.1016/j.learninstruc.2019.04.004.

[20] A. Littlejohn, C. Milligan, and A. Margaryan, "Charting collective knowledge: supporting self-regulated learning in the workplace," *Jnl. of Workplace Learning,* vol. 24, pp. 226-238, 2012, doi: 10.1108/13665621211209285.

[21] R. Crick and J. Bentley, "Becoming a resilient organisation: integrating people and practice in infrastructure services," *Int. Jnl. of Sustainable Engineering,* vol. 13, no. 6, pp. 423-440, 2020, doi: 10.1080/19397038.2020.1750738.

[22] "The Future of Jobs," World Economic Forum, Geneva, Switzerland, 2020. [Online]. https://www.weforum.org/reports/the-future-of-jobs-report-2020

[23] N. Hutchison *et al.*, "Atlas: Effective Systems Engineers and Systems Engineering," Systems Engineering Research Center (SERC), Hoboken, NJ, 2020, vol. SERC-2020-TR-007-A.

[24] N. Hutchison *et al.*, "Evolution of the Helix Project: From Investigating the Effectiveness of Individual Systems Engineers to Systems Engineering Organizations," *INCOSE Int. Symposium,* vol. 29, no. 1, pp. 652-668, 2019, doi: 10.1002/j.2334-5837.2019.00626.x.

[25] R. Crick, T. McDermott, and N. Hutchison, "Learning Design for Sustainable Development," *Jnl. of Education, Teaching and Social Studies,* vol. 3, no. 3, pp. 15-43, 2021, doi: 10.22158/jetss.v3n3p15.

[26] R. Deakin Crick. (2005) Learning Power: Dynamic Assessment for Learning. *The Leader: Secondary Heads Association.*

[27] M. Jaros and R. Deakin Crick, "Personalised Learning in the Post Mechanical Age," *Jnl. of Curriculum Studies,* vol. 39, no. 4, pp. 423-440, 2007.

[28] R. Deakin Crick, "Inquiry-based learning: reconciling the personal with the public in a democratic and archaeological pedagogy," *Curriculum Jnl.,* vol. 20, no. 1, pp. 73 - 92, 2009. doi: 10.1080/09585170902764021

[29] C. Argyris, "Double loop learning in organizations," *Harvard Business Review,* vol. 55, no. 5, pp. 115-125, 1977.

[30] I. Falconer, A. Littlejohn, and L. McGill, "Fluid Learning: Vision for lifelong learning in 2030," in *Open Education 2030. European Commission JRC-IPTS Call for Vision Papers. Part I: Lifelong Learning*, 2013, pp. 12-19.

[31] T. Ley, "Knowledge structures for integrating working and learning: A reflection on a decade of learning technology research for workplace learning," *British Jnl. of Educational Technology,* vol. 51, no. 2, pp. 331-346, 2020, doi: 10.1111/bjet.12835.

[32] S. Dennerlein *et al.*, "KnowBrain: An Online Social Knowledge Repository for Informal Workplace Learning," Springer Int. Publishing, 2015, pp. 509-512.

[33] T. Ley *et al.*, "Scaling informal learning at the workplace: A model and four designs from a large-scale design-based research effort," *British Jnl. of Educational Technology,* vol. 45, no. 6, pp. 1036-1048, 2014, doi: 10.1111/bjet.12197.

[34] S. Dawson, N. Mirriahi, and D. Gasevic, "Importance of Theory in Learning Analytics in Formal and Workplace Settings," *Jnl. of Learning Analytics,* vol. 2, no. 2, pp. 1-4, 12/07 2015, doi: 10.18608/jla.2015.22.1.

[35] S. Dawson, S. Joksimovic, O. Poquet, and G. Siemens, "Increasing the Impact of Learning Analytics," in *Proc. 9th Int. Conf. on Learning Analytics & Knowledge*, Tempe, AZ, USA, 2019, doi: 10.1145/3303772.3303784.

[36] J. W. X. Ng and O. Poquet, "Exploratory study of analytics-based technologies used for corporate learning and development," *Centre for*

Work & Learning, Institute for Adult Learning, Singapore Univ. of Social Sciences, 2020.

[37] A. Ruiz-Calleja, L. P. Prieto, T. Ley, M. J. Rodríguez-Triana, and S. Dennerlein, "Learning Analytics for Professional and Workplace Learning: A Literature Review," *Proc. 12th European Conf. Technology-Enhanced Learning,* Tallinn, Estonia: Springer, Dec. 2017, pp. 164–178. doi: 10.1007/978-3-319-66610-5_13.

[38] M. Bloomer, "Young Lives, Learning & Transformation: Some Theoretical Considerations," *The Oxford Review of Education,,* vol. 27, no. 3, pp. 429-447, 2001.

[39] M. Bloomer and P. Hodkinson, "Learning Careers: continuity and change in young people's dispositions to learning," *British Educational Research Jnl.,* vol. 26, no. 5, pp. 583-597, 2000.

[40] A. Sfard and A. Prusak, "Telling Identities: In Search of an Analytic Tool for Investigating Learning as a Culturally Shaped Activity," *Educational Researcher* vol. 34, no. 4, pp. 14-22, 2005.

[41] J. Lave and E. Wenger, *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge Univ. Press, 1991, p. 139.

[42] J. L. Lemke, "Across the scales of time: artifacts, activities, and meanings in ecosocial systems," *Mind, Culture, and Activity,* vol. 7, no. 4, pp. 273-290, 2000.

[43] M. Abrandt Dahlgren, *"Becoming" a professional : : an interdisciplinary analysis of professional learning*. Dordrecht: Springer (in eng), 2011, p. 261.

[44] J. Saint, A. Whitelock-Wainwright, D. Gasevic, and A. Pardo, "Trace-SRL: A Framework for Analysis of Microlevel Processes of Self-Regulated Learning From Trace Data," *IEEE Transactions on Learning Technologies,* vol. 13, no. 4, pp. 861-877, 2020, doi: 10.1109/tlt.2020.3027496.

[45] M. Siadaty, D. Gašević, and M. Hatala, "Associations between technological scaffolding and micro-level processes of self-regulated learning: A workplace study," *Computers in Human Behavior,* vol. 55, pp. 1007-1019, 2016, doi: 10.1016/j.chb.2015.10.035.

[46] B. Renner *et al.*, "Computer-supported reflective learning: how apps can foster reflection at work," *Behaviour & Information Technology,* vol. 39, no. 2, pp. 167-187, 2020/02/01 2020, doi: 10.1080/0144929X.2019.1595726.

[47] V. Pammer-Schindler and C. Rosé, "Data-Related Ethics Issues in Technologies for Informal Professional Learning," *Int. Jnl. of Artificial Intelligence in Education,* 2021, doi: 10.1007/s40593-021-00259-x.

[48] B. Schreurs and M. De Laat, "Network awareness tool - learning analytics in the workplace: detecting and analyzing informal workplace learning," in *Proc. 2nd Int. Conf. on Learning Analytics and Knowledge*, Vancouver, British Columbia, Canada, 2012, doi: 10.1145/2330601.2330620.

[49] R. Kaliisa, B. Rienties, A. I. Mørch, and A. Kluge, "Social learning analytics in computer-supported collaborative learning environments: A systematic review of empirical studies," *Computers and Education Open,* vol. 3, p. 100073, 2022, doi: 10.1016/j.caeo.2022.100073.

[50] J. Tomasson Goodwin, J. Goh, S. Verkoeyen, and K. Lithgow, "Can students be taught to articulate employability skills?," *Education + Training,* vol. 61, no. 4, pp. 445-460, 2019, doi: 10.1108/ET-08-2018-0186.

[51] "O*NET Resource Center." https://www.onetcenter.org

[52] "European Skill/Competences, qualifications and Occupations " https://ec.europa.eu/esco

[53] K. Kitto, N. Sarathy, A. Gromov, M. Liu, K. Musial, and S. Buckingham Shum, "Towards skills-based curriculum analytics: can we automate the recognition of prior learning?," in *Proc. Tenth Int. Conf. on Learning Analytics & Knowledge*, Frankfurt, Germany, 2020, doi: 10.1145/3375462.3375526.

[54] A. Gromov, A. Maslennikov, N. Dawson, K. Musial, and K. Kitto, "Curriculum profile: modelling the gaps between curriculum and the job market," in *13th Int. Conf. on Educational Data Mining,* 2020. https://opus.lib.uts.edu.au/bitstream/10453/143066/2/paper_59.pdf

[55] "Analyse Workforce Capability (FutureTRACK)." Univ. of Technology Sydney. https://www.uts.edu.au/industry/corporate-training/analyse-workforce-capability

[56] "eDoer: your Personal Curriculum." https://labs.tib.eu/edoer/

[57] M. Tavakoli, A. Faraji, S. Mol, and G. Kismihók, "OER Recommendations to Support Career Development," in *IEEE Frontiers in Education Conf.*, 2020. [Online]. https://arxiv.org/abs/2006.00365

[58] B. Berendt, A. Littlejohn, and M. Blakemore, "AI in education: learner choice and fundamental rights," *Learning, Media and Technology,* vol. 45, no. 3, pp. 312-324, 2020.

[59] N. Dawson, M.-A. Rizoiu, B. Johnston, and M.-A. Williams, "Adaptively selecting occupations to detect skill shortages from online job ads," in *Int. Conf. on Big Data*, 9-12 Dec., 2019. [Online]. 10.1109/bigdata47090.2019.9005967

[60] K. Lanaj, T. A. Foulk, and A. Erez, "Energizing leaders via self-reflection: A within-person field experiment," *Jnl. of Applied Psychology,* vol. 104, no. 1, pp. 1-18, 2019, doi: 10.1037/apl0000350.

[61] S. Buckingham Shum, Á. Sándor, R. Goldsmith, R. Bass, and M. McWilliams, "Towards Reflective Writing Analytics: Rationale, Methodology and Preliminary Results," *Jnl. of Learning Analytics,* vol. 4, no. 1, pp. 58-84, 2017, doi: 10.18608/jla.2017.41.5.

[62] S. Knight *et al.*, "AcaWriter: A Learning Analytics Tool for Formative Feedback on Academic Writing," *Jnl. of Writing Research,* vol. 12, no. 1, pp. 141-186, 2020, doi: 10.17239/jowr-2020.12.01.06.

[63] C. Lucas, S. Buckingham Shum, M. Liu, and M. Bebawy, "Implementing AcaWriter as a Novel Strategy to Support Pharmacy Students' Reflective Practice in Scientific Research," *American Jnl. of Pharmaceutical Education,* p. 8320, 2021, doi: 10.5688/ajpe8320.

[64] M. Liu, K. Kitto, and S. Buckingham Shum, "Combining factor analysis with writing analytics for the formative assessment of written reflection," *Computers in Human Behavior,* vol. 120, p. 106733, 2021, doi: 10.1016/j.chb.2021.106733.

[65] V. Kovanović *et al.*, "Understand students' self-reflections through learning analytics," in *Proc. 8th Int. Conf. on Learning Analytics and Knowledge*, Sydney, New South Wales, Australia, 2018, doi: 10.1145/3170358.3170374.

[66] A. Gibson, K. Kitto, and P. Bruza, "Towards the Discovery of Learner Metacognition From Reflective Writing," *Jnl. of Learning Analytics,* vol. 3, no. 2, pp. 22-36, 2016, doi: 10.18608/jla.2016.32.3.

[67] T. D. Ullmann, "Automated Analysis of Reflection in Writing: Validating Machine Learning Approaches," *Int. Jnl. of Artificial Intelligence in Education,* vol. 29, no. 2, pp. 217-257, 2019, doi: 10.1007/s40593-019-00174-2.

[68] Y. Cui, A. F. Wise, and K. L. Allen, "Developing reflection analytics for health professions education: A multi-dimensional framework to align critical concepts with data features," *Computers in Human Behavior,* vol. 100, pp. 305-324, 2019/11/01 2019, doi: 10.1016/j.chb.2019.02.019.

[69] M. Liu, S. Buckingham Shum, E. Mantzourani, and C. Lucas, "Evaluating machine learning approaches to classify pharmacy students' reflective statements," in *20th Int. Conf. on Artificial Intelligence in Education*, Chicago, June 2019, 2019.

[70] J. Dewey, *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. Boston: Heath and Co, 1933.

[71] L. G. Katz, "Dispositions: Definitions and Implications for Early Childhood Practices. Perspectives from ERIC/EECE: A Monograph Series, No. 4," ERIC Clearinghouse on Elementary and Early Childhood Education, Urbana, IL, 1993.

[72] R. D. Crick, "Deep Engagement as a Complex System: Identity, Learning Power and Authentic Enquiry," in *Handbook of Research on Student Engagement*, L. Christenson, L. Reschly, and C. Wylie Eds. New York,: Springer. , 2012, ch. Chapter 32, pp. 675-694.

[73] P. Bourdieu, *Language and Symbolic Power* Cambridge, Massachusetts: Harvard Univ. Press, 1991.

[74] D. McKnight, "An Inquiry of NCATE's Move into Virtue Ethics by Way of Dispositions (Is This What Aristotle Meant?)," *Educational Studies Jnl. of the American Educational Studies Assoc,* vol. 35, no. 3, pp. 19-230, 2004.

[75] S. Buckingham Shum and R. Deakin Crick, "Learning dispositions and transferable competencies: pedagogy, modelling and learning analytics," in *Proc. 2nd Int. Conf. on Learning Analytics and Knowledge*, Vancouver, British Columbia, Canada, 2012, doi: 10.1145/2330601.2330629.

[76] R. Deakin Crick, B. McCombs, A. Haddon, P. Broadfoot, and M. Tew, "The ecology of learning: factors contributing to learner-centred classroom cultures," *Research Papers in Education,* vol. 22, no. 3, pp. 267-307, 2007 2007, doi: 10.1080/02671520701497555.

[77] R. Deakin Crick, *Learning Power in Practice: A Guide for Teachers*. London: Paul Chapman, 2006.

[78] R. Deakin Crick, "Learning how to learn: the dynamic assessment of learning power," *Curriculum Jnl.,* vol. 18, no. 2, pp. 135 - 153, 2007. doi: 10.1080/09585170701445947

[79] R. Crick, *It's a Gift: Disposed to Learn*. Melbourne: Corwin Press, 2018.

[80] R. Deakin Crick, "Learning to Learn: a complex systems perspective," in *Learning to Learn: Int. Perspectives from Theory and Practice*, R. Deakin Crick, C. Stringer, and K. Ren Eds. London: Routledge, 2014.

[81] K. Ren and R. Deakin Crick, "Empowering underachieving adolescents: an emancipatory learning perspective on underachievement," *Pedagogies: An Int. Jnl.,* vol. 8, no. 3, pp. 235-254, 2013/07/01 2013, doi: 10.1080/1554480x.2013.795670.

[82] R. Deakin Crick, H. Jelfs, S. Huang, and Q. Wang, "Learning Futures Final Report," Paul Hamlyn Foundation, London, 2011.

[83] K. Ren and R. Deakin Crick, "探索有效身学之指：学能量"及其'," 高等学校文科学文 摘 (China Univ. Academic Abstracts), vol. 29, no. 3, pp. 82-83, 2012.

[84] R. Deakin Crick and H. Jelfs, "Spirituality, Learning and Personalisation: exploring the relationship between spiritual development and learning to learn in a faith-based secondary school. ," *Int. Jnl. of Children's Spirituality,* vol. 16, no. 3, pp. 197-217, 2011.

[85] T. Small and R. Deakin Crick, "Learning and Self-Awareness: an enquiry into Personal Development in Higher Education," in "ViTaL Partnerships Research and Development Report No 8," ViTaL Partnerships, Bristol, 2008.

[86] D. Tempelaar, B. Rienties, and Q. Nguyen, "The Contribution of Dispositional Learning Analytics to Precision Education," *Educational Technology & Society,* vol. 24, no. 1, pp. 109-122, 2021. [Online]. https://www.jstor.org/stable/26977861.

[87] D. T. Tempelaar, B. Rienties, and B. Giesbers, "In search for the most informative data for feedback generation: Learning analytics in a data-rich context," *Computers in Human Behavior,* vol. 47, pp. 157-167, 2015/06/01/ 2015, doi: 10.1016/j.chb.2014.05.038.

[88] "WILD Learning." https://wildlearn.co

[89] G. Barratt-See, M. Cheng, R. Deakin Crick, and S. Buckingham Shum, "Assessing Resilient Agency with CLARA: Empirical Findings from Piloting a Visual Analytics Tool at UTS," in *Proc. UniSTARS 2017: Univ. Students, Transitions, Achievement, Retention & Success*, Adelaide, 1-4 July, 2017, 2017.

[90] R. Crick and J. Bentley, "Becoming a resilient organisation: integrating people and practice in infrastructure services," *Int. Jnl. of Sustainable Engineering,* pp. 1-18, 2020, doi: 10.1080/19397038.2020.1750738.

[91] "Learning Journeys at UTS: Stories for Professionals (Hunter Water Videos)." Univ. of Technology Sydney. https://www.uts.edu.au/research-and-teaching/teaching-and-research-integration/learning-journeys/professional-staff

[92] W. Harlen and R. Deakin Crick, "Testing and Motivation for Learning," *Assessment in Education,* vol. 10, no. 2, pp. 169-207, 2003.

[93] J. P. Bersin, J. Schwartz, and B. van der Vyver, "Rewriting the Rules for the Digital Age (Deloitte Global Human Capital Trends Report)," Deloitte Univ. Press, Westlake, TX, 2017. [Online]. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/central-europe/ce-global-human-capital-trends.pdf

[94] R. Crick, "Learning Analytics: Layers, Loops and Processes in a Virtual Learning Infrastructure," in *Handbook of Learning Analytics & Educational Data Mining (1st Ed.)*, G. Siemens and C. Lang Eds.: Society for Learning Analytics Research, 2017.

[95] X. Ochoa, "Multimodal Learning Analytics - Rationale, Process, Examples, and Direction," in *The Handbook of Learning Analytics (2nd Edition)*, C. Lang, G. Siemens, A. Wise, D. Gasevic, and A. Merceron Eds., 2022, pp. 54-65.

[96] V. Echeverria, R. Martinez-Maldonado, and S. Buckingham Shum, "Towards Collaboration Translucence: Giving Meaning to Multimodal Group Data," in *Proc. of ACM CHI: Conf. (CHI'19). ACM, New York, NY, USA, Paper 39,* 2019, doi: 10.1145/3290605.3300269.

[97] R. Martinez-Maldonado, K. Mangaroska, J. Schulte, D. Elliott, C. Axisa, and S. Buckingham Shum, "Teacher Tracking with Integrity: What Indoor Positioning Can Reveal About Instructional Proxemics," *ACM Interactions on Mobile, Wearable & Ubiquitous Technologies,* vol. 4, no. 1, pp. Article 22, pp.1-27, 2020, doi: 10.1145/3381017.

[98] W. M. Newman, M. A. Eldridge, and M. G. Lamming, "PEPYS: generating autobiographies by automatic tracking," in *Proc. European Conf. on Computer-Supported Cooperative Work*, Amsterdam, The Netherlands, 1991.

[99] H. Alwahaby, M. Cukurova, Z. Papamitsiou, and M. Giannakos, "The evidence of impact and ethical considerations of Multimodal Learning Analytics: A Systematic Literature Review," in *The Multimodal Learning Analytics Handbook*, D. Di Mitri, M. Giannakos, R. Hammad, X. Ochoa, K. Sharma, and D. Spikol Eds.: Springer, 2022.

Simon Buckingham Shum received a B.Sc. (Honours) in psychology from the University of York, UK (1987), an M.Sc. in ergonomics from University College London, UK (1988), and a Ph.D. in human-computer interaction from University of York, UK (1992).

From 1995-2014 he was at the Knowledge Media Institute, The Open University UK, and since 2014 has been Professor of Learning Informatics at the University of Technology Sydney, as inaugural director of the Connected Intelligence Centre. He has published widely on how software can help make thinking visible, in fields spanning computer-supported cooperative work, hypertext, design rationale, semantic web, computational argumentation, educational technology, learning analytics and AI in education. He was a founding General Editor of the *Journal of Interactive Media in Education* (1996-2004) and a co-founder and Vice-President of the *Society for Learning Analytics Research.*

Allison Littlejohn is a learning scientist, specializing in professional and digital learning. Her work has made contributions to the understanding of how people learn for work in diverse contexts and cultures across the Energy, Finance, Health, Education and Int. Development sectors.

Allison is Director of the UCL Knowledge Lab, University College London and is a Professor in the UCL Institute of Education. She has held research Chairs at five UK universities and has experience of strategic leadership in education, as Dean (Learning & Teaching), College of Social Sciences, University of Glasgow; Academic Director of Digital Innovation at the Open University (2015-2019); Founding Director of the Caledonian Academy at Glasgow Caledonian University (2006 – 2014), where she was Senior Researcher for Royal Dutch Shell (2008-2010), leading a partnership around Knowledge Innovation & Development.

Kirsty Kitto received a Ph.D. in theoretical physics from the Flinders University of South Australia (2006), and undergraduate degrees BSc(Hons) (1998), BA (2006), BCompSci (2004), all from the Flinders University of South Australia.

She is currently an Associate Professor in Data Science at the University of Technology Sydney (UTS) where her research at the Connected Intelligence Centre aims to support lifelong personalised learning using techniques from Learning Analytics, Cognitive Science and Complex Systems Science. Prior to that she was based at the Queensland University of Technology (QUT), where she was awarded an Australian Postdoctoral Fellowship from the ARC to model language and cognition in context. She has also

Ruth Crick is CEO of WILD Learning and Visiting Professor of Learning Analytics at the University of Technology Sydney. Her research has led in the theorization and practical development of learning for self-leadership in a complex world, systemically integrating divergent imperatives for effectiveness: the personal and the public, identity and performance, agency and structure, the human and the digital.

Working with a collaborative business model, operating at the interface of research, policy, practice and enterprise, Ruth has co-developed a digital learning journey platform, architected on the basis of a single-view-of-the-learner, capable of providing diagnostic tools for supporting self-directed change, developing 'resilient agency' and using machine learning to support 'purposeful conversations'. She works with industry partners to develop corporate learning power as a rigorous and measurable process that can be integrated with business strategy to catalyse transformation, improve performance and reduce the costs of failure. She works across the corporate/education divide applying these ideas to school transformation and to the 'behaviour change at scale' challenges of the UN Sustainable Development Goals.