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The "Soil Skills" Pedagogical Approach Conjugated With Soil Judging Contests

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The inherent complexity of soil and its interactions with Earth's diverse spheres, including the atmosphere, biosphere, hydrosphere, lithosphere within the ecosphere, and anthroposphere, requires that soil science specialists and students develop not only a profound understanding of soil science, but also the ability to collaborate across various disciplines to address these complex challenges. Equipping students with the necessary knowledge, skills, and attitudes to tackle the intricate and dynamic issues of the 21st century, spanning soil science, water sciences, hydropedology, geology, agronomy, geotechnical engineering, sedimentation, waste management, recycling, and environmental management, is of paramount importance. In response, innovative pedagogical approaches that integrate classroom learning from diverse soil science courses with practical skills and field-based competencies are needed. This paper suggests merging our own "Soil Skills" (SSK) pedagogical method with the "Soil Judging Contest" (SJC), a teaching approach supported by the American Society of Agronomy and the Soil Science Society of America since 1961. This integration aims to enhance the holistic, harmonized, interdisciplinary, and enthusiastic nature of soil science education. Both the SSK and SJC approaches received positive feedback from students and demonstrated significant improvements in academic performance. Our study begins with an in-depth exploration of the SSK contest, followed by an overview of the pertinent aspects of the SJC. Subsequently, we offer a comparative analysis of the complementarity of these two approaches. Finally, in the concluding remarks, we summarize the strengths of the implemented SSK and outline prospective applications. Our findings underscore the unique advantages of combining SSK and SJC approaches in delivering comprehensive, problem-based, and practical field-learning experiences. This combination approach closely aligns with applied scenarios that demand multidisciplinarity and interdisciplinarity perspectives, preparing students for their future professional careers, and enabling the practical application of their soil science knowledge in real-world contexts.

Keywords: soil science, inquiry-based learning, scaffolding in course levels, teaching and learning, pedagogical practices

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INTRODUCTION

Soil science education plays a crucial role in understanding and managing one of our planet's most critical resources—the soil. Soil is a complex and dynamic ecosystem that supports agriculture, forestry, environmental sustainability, and overall ecosystem health. Soil is also identified as being integral and central to many of the challenges facing ecological and societal systems, including the challenges of food, water, and energy security, environmental impact and remediation, loss of biodiversity, effective land use planning and management, and climate change abatement, all of which contribute to human health and wellbeing (Hartemink and McBratney, 2008; Flannery, 2011; Janzen et al., 2011; Koch et al., 2013).

For students and industry stakeholders who require in-service training and practical experience, the focus on a multi-disciplinary approach is essential (Field et al., 2017). As articulated by Hartemink. (2006), soil science cannot operate in isolation; it must actively engage with multidisciplinary or interdisciplinary teams and establish connections with other fields of study. Díaz-Fierros Viqueira. (2015) stated that "Soil in all its complexity cannot be understood without some basic knowledge of geology, biology, physics, chemistry, and mathematics." The sub-disciplines into which soil science is divided may represent fields of knowledge that should be investigated further through the application of certain techniques and specific concepts. However, they should never represent hermetic spaces delimited by insurmountable barriers, as is often the case. Students and lifelong learning soil science professionals should understand the concept of soil security in connection with food, water, and energy security edifices (Brevik et al., 2022). As envisioned by McBratney et al. (2014), such security brings a social aspect to the soil security concept, the idea that the public, government officials, and others need to bond to the soil not only through traditional aspects of soil's conditions, capabilities, and capital but also via soil connectivity, describing links with stakeholders, society at large and the policy arena, including soil codification describing links with environmental rules and regulations. These aspects of connectivity have strong links to soil knowledge, which means they would be supported by well-considered educational strategies. Soil scientists emphasize the need for a holistic approach to understanding the multifaceted nature of soils, especially in developing countries. Bridges and Catizzone. (1996) underscored viewing soils systemically while recognizing their labyrinthine interconnectedness, which poses challenges to human comprehension. Adopting a systems perspective leads to a more profound grasp of soil-related matters and enhances decision-making in their management (Vogel et al., 2018). To revamp the soil science curriculum, one potential direction is the adoption of the "know," "know of," and "aware of" soil framework proposed by Field. (2019). This student-centric concept fosters learning environments either concentrated on in-depth soil science expertise ("know soil") or on the application of this knowledge in contexts where soil science is just a component ("know of soil"). This approach facilitates the crafting of a curriculum that merges specialized knowledge with a holistic learning setting, driven by ominous problems (Brevik et al., 2022).

Consequently, it is essential and in congruence with the Sustainable Development Goal (SDG) 4 "Quality Education" to teach individuals the science of soils to ensure responsible land use, climate change mitigation, and resource conservation, in particular, clean water and sanitation, among others. In addition to a better scientific understanding, major developments have been made in the perception of both the ecological and non-ecological functions of soils in providing fundamental ecosystem goods and services (Lal and Stewart, 2013; Urbańska and Charzyński, 2021). This means that those who self-identify as soil scientists or have soil science expertise will need to engage with a variety of stakeholders to pinpoint what the problems are, and in doing so, work towards providing solutions to these ever-increasing complex environmental problems. This, in part, has resulted in the teaching of soil science no longer being confined to its traditional founding in agriculture and agronomy. As a discipline, soil science has expanded its scope to other specializations in environmental sciences, botany, forestry, ecology, geography, geology, soil mechanics, and hydrology (Hartemink et al., 2014). Graduates not only need to acquire knowledge, skills, and capabilities in traditional soil sciences, but they must also work between and across other disciplines. As pointed out by Bouma. (2010), solving complex contemporary problems will not solely rely on the objective (science) answers of "right or wrong," but also the relativistic (societal and political) answers that consider decisions as "better" or "worse." Subdisciplines of soil sciences, such as pedology, soil physics, soil chemistry, and soil microbiology, still operate somewhat independently. For example, a combined expertise of soil physicists and pedologists in hydropedology offers a basic package, to be completed by soil chemists and biologists, to interdisciplinary teams studying ecosystem services in line with the UN SDGs (Bouma, 2023). This should change when focusing on providing effective contributions of soil scientists to SDGs and communities of scientific practices to form a suitable vehicle for their integration (Bouma, 2019a). We recall that historically, despite soils' inherent uniqueness and tortuous integration within the natural world, the "soil system" endured a period of diminished recognition, during the "environmental wave" spanning from the 1970s to the late 1980s (Díaz-Fierros Viqueira, 2015). This era witnessed the agricultural revolution's surge, accompanied by the intensive use of synthetic fertilizers and other agrochemicals and the relentless pursuit of maximized agricultural yields, giving rise to substantial environmental concerns. Consequently, the study of soils and other traditional aspects of agrarian production underwent a gradual decline in significance, while environmental research topics garnered the favor of both funding agencies and the general public.

Soil science students, as future experts, have to learn how to make, coordinate, and manage "*ad hoc*" social learning groups on, e.g., "the problem of secondary salinization caused by seawater intrusion in a plant-cultivated area." The students should be trained to simulate situations when the brainstormed recipes "what can be done," "what is worth doing," and "what should not be done" are transmitted within the groups involving "experts" of various calibers and laymen (Krzywoszynska, 2019). Furthermore, future graduates need to be able to engage with scientists from many disciplines, policy experts, practitioners (e.g., farmers), and users of relevant soil information (Wessolek, 2006).

Therefore, there is a need for innovative pedagogical approaches that integrate knowledge learned in classrooms from various courses of the soil science curriculum along with developing practical skills and field-based competencies in soil education. Unfortunately, in contemporary soil science research, the heavy reliance on controlled laboratory experiments, mathematical models, and remote sensing techniques has overshadowed genuine fist-person direct field observations and measurements (Díaz-Fierros Viqueira, 2015).

Soil Skills (SSK) and the Soil Judging Contest (SJC) exemplify innovative pedagogical techniques designed to enhance students' engagement and enthusiasm within dynamic and stimulating learning environments (Rees and Johnson, 2020; Al-Ismaily et al., 2021). These educational methodologies transcend traditional lecture-based instruction by embracing problem-based learning and active teaching strategies, with the primary objective of providing students with hands-on experiences. Furthermore, the extracurricular nature of these approaches, coupled with the element of competition among participating teams, serves as a motivational catalyst, inspiring students to immerse themselves in their knowledge fields with genuine enthusiasm.

SJC is a competitive soil science educational program organized at various universities across the United States. and the world (Galbraith and Thompson, 2014; Rees and Johnson, 2020). The competing teams evaluate crucial soil properties and morphogenic diagnostic features (e.g., soil texture, structure, moisture content, soil color, epi-endo-pedons, etc.), and make informed judgments based on their observations and knowledge of soil science principles. The winning teams at the national level will then compete at the international level [See Official Handbook Inaugural International Soil Judging Contest (World Congress of Soil Science, 2014)].

While SJC has a long history of successful organization at local, regional, and national levels, SSK is a recent initiative, having been launched in 2018 by the Department of Soils, Water, and Agricultural Engineering (SWAE) at Sultan Qaboos University (SQU) in Oman. In contrast to SJC, which primarily emphasizes soil profile description and landscape interpretation, SSK challenges participating students to apply an interdisciplinary approach, synthesizing knowledge acquired from various aspects of the soil science curriculum to address real-world case studies that illustrate the interconnectedness of soil, water, landscape, and community (Al-Ismaily et al., 2021).

It is noteworthy that recently, the concept of "citizens' science" emerged, in particular, in engaging local communities in soil sciences endeavors (Pino et al., 2022).

In this study, we propose the conjugation and integration of the SJC and SSK approaches to maximize the learning experience of soil science education in a holistic, harmonized, interdisciplinary, and enthusiastic manner. The conjugation of these two approaches provides students and future soil science professionals with the ability to gain novel multidisciplinary knowledge and dexterity for making connections between the variety of ecosystem services that soil provides.

The paper's structure unfolds as follows: Firstly, we delve into an in-depth exploration of the SSK contest. Following that, we shift our focus to the SJC. Subsequently, we provide a comparative analysis of these two approaches. Lastly, we offer our concluding remarks and outline future perspectives.

THE SOIL SKILLS (SSK) CONTEST

Description of the SSK Approach

Global platforms like "World Skills"[1] and the Dutch initiative of "Wetskills"[2] focus on professional training and water technologies, correspondingly. The SQU through the Department of SWAE collaborates with the Netherlands Embassy in Oman to organize "Wetskills" events, conducted annually in 2017–2020 and—after a COVID gap—in 2022–2023. These engagements provided SWAE soil scientists with insights into Dutch procedures, such as pitching, coaching, team evaluations, and awarding. Drawing from this experience, SQU unveiled the SSK program in January 2018. Unlike "Wetskills," which is centered on water-related topics, and is prevalently based on "in-auditorium" interactions, SSK adopts a cross-disciplinary lens. Predominantly field-based, SSK strengthens participants' proficiency in soil-related practical tasks, but at the same time, requires background and mental acuity acquired in other BSc-level courses taught at SQU in the "Soil Sciences" program. Unlike the varied international composition of qualifications, ages, languages, and nationalities of "Wetskills" participants, SSK participants are more homogenous.

Competitions pertaining to soil profile descriptions or SJC have been previously documented (Field, 2019; Rees and Johnson, 2020). However, our competition encompasses a wider range of cross-disciplinary standards. SSK module, now a part of the Soil and Water Winter Tour (SWWT) course (Al-Maktoumi et al., 2016; Al-Ismaily et al., 2019), which is required and elective in Soil Science and Water Technology, respectively, BSc programs at SQU-SWAE.[3]

The SWWT course structure comprises 5 days of intensive training, instrument familiarity, field explorations, and mini-competitions. The first 4 days involve guidance from the primary educator, skill acquisition, hands-on field experiences, and short challenges, such as quick assessments of soil properties, rapid soil surveys, or evaluating water flow rates in a wadi channel (fluvial valley that only flows during a rainy season). The final, fifth day, is dedicated to the SSK contest. This day is the

[1]https://worldskills.org/
[2]https://wetskills.com/
[3]https://www.squ.edu.om/agriculture/Academic-Department/Soils-Water-and-Agricultural-Engineering/Description

culmination of SWWT, with a continuous competition between the student groups.

This course parallels foundational soil science courses, like SOIL 1113 (Abit Jr et al., 2018), in its complexity. Yet, the SSK distinguishes itself by placing students, for example, in authentic scenarios of arid land, salinized soils, falaj, and modern irrigation in Oman. The SSK inculcates and evaluates holistic understandings of integrated soil sciences (Bouma, 2019b; de Sousa et al., 2019).

In essence, the SSK challenge pushes undergraduates to confront diverse soil and water dilemmas in Oman in an exhilarating setting. For instance, the 2018 batch tackled a project focusing on enhancing home gardening in specific Omani regions to address waterlogging and secondary salinity issues. We adopted the problem-based learning methodology, inspiring students to address and resolve challenges emblematic of Earth's dynamics.

The SSK competition integrates specific outcome-oriented objectives, aligning them with the broader goals of the SQU Soil Science curriculum. One key objective is to bolster students' ability to think critically, equipping them with the potential to deal with current soil challenges. These challenges can often be wicked, open to multiple interpretations, and have various potential resolutions, as noted by Cantor et al. (2015). Another objective is to merge classroom theory with field research, covering topics that intersect with various geosciences, such as geoengineering, hydropedology, agroecology, and more, as referenced by Field et al. (2017). Another goal is to encourage students to explore the relationship between soil, water, and societal factors and to extract vital information to address their assigned tasks. Lastly, providing students with practical training using cutting-edge field equipment and methodologies in soil and water research rounds out these objectives.

The SSK Learning Strategy

The SSK is an advanced active learning strategy for senior Soil Sciences undergraduates at SQU), Oman. This pedagogical model amalgamates several strategies:

(i) Embracing active problem-based learning as highlighted by Lukes et al. (2020) and Schmidt (1983), underscoring inquiry-driven learning facets essential for soil science graduates. This encompasses 1) teamwork spirit, 2) synergistic cooperation, 3) analytical problem-solving, 4) a full understanding of soil concepts, and 5) adept utilization of appropriate tools and methodologies (Lin, 2005; Wilding and Lin, 2006; Field et al., 2011; Hartemink et al., 2014).
(ii) Induction of scaffolding (Calder, 2015; Quintana et al., 2018), where students gradually transition towards autonomous learning while delving into hard assignments.
(iii) Introducing inter-team competition, an approach shown to be impactful across numerous science, technology, engineering, and mathematics (STEM) disciplines, inclusive of Soil Sciences (see, e.g., Sulzman, 2004; Barbarick, 2010; Hupy, 2011).
(iv) Adhering to the Data-Information-Knowledge-Wisdom (DIKW) progression model (Ackoff, 1989). This DIKW paradigm illustrates the evolution from raw data acquisition to its insightful application, particularly in specific research contexts (Frické, 2019).

Our tailored teaching techniques bolster students' competence in applying their multifaceted abilities to untangle the mechanisms of insidious events and "in the field" conundrums. The SSK approach invigorates students with meta-cognitive, inquiry-driven learning traits.

SSK Contest Description

Over the initial 4 days of the SSK challenge, students undergo intensive training, which encompasses small-scale tasks, that refresh their understanding of soil concepts, and fosters teamwork, while using modern field equipment and tools. **Figure 1** illustrates a step-by-step procedure of the SSK.

On the fifth day, two groups, each consisting of 5–10 students, compete for the SSK award. From the outset, students nominate their team leaders, who are then granted the authority to handpick their team members. This procedure and team structure ensured the groups grew familiar with one another as the challenge advanced from day one through day five. The selection of team members consists of a discreet session where the leaders alternate in choosing members, beginning with those perceived as the most skilled down to the least. This selection order remains undisclosed to the other team members. Moreover, the instructors provide the leaders with confidential guidance, which includes fostering unity and participation from all members, prioritizing task completion, celebrating even minor achievements, continuously assessing and refining team performance, and embodying exemplary leadership.

Prior to the beginning of the SSK challenge, a field site with convoluted soil-related problems is pre-selected by several SWAE faculty members and technicians. These members, experts in the domains of soil and water science, also compose the Jury. They are tasked with gauging team performance against a predetermined set of criteria related to the specific problem present in the chosen field.

Participants are equipped with challenge protocols, directives, and evaluation criteria. Additionally, each team is provided a blank field notebook, intended for the duration of the challenge. Upon the contest's conclusion, this notebook, filled with illustrations, computations, and notes, alongside student identifications, is to be presented to the Jury for scrutiny.

The challenge avails a range of soil and water field instruments, kits, and the General Soil Map of Oman, all distributed to the teams (**Figures 2A–G**). Genuine case studies and tasks, depicting soil-water-landscape-community interconnections, are presented on the competition day. Examples of such tasks including: i) Describing soil profiles and estimating physicochemical parameters, ii) Investigating challenges and proposing agroengineering solutions in sabkha ecosystems, iii) Addressing urban flood management by analyzing, planning, and proposing solutions, iv)

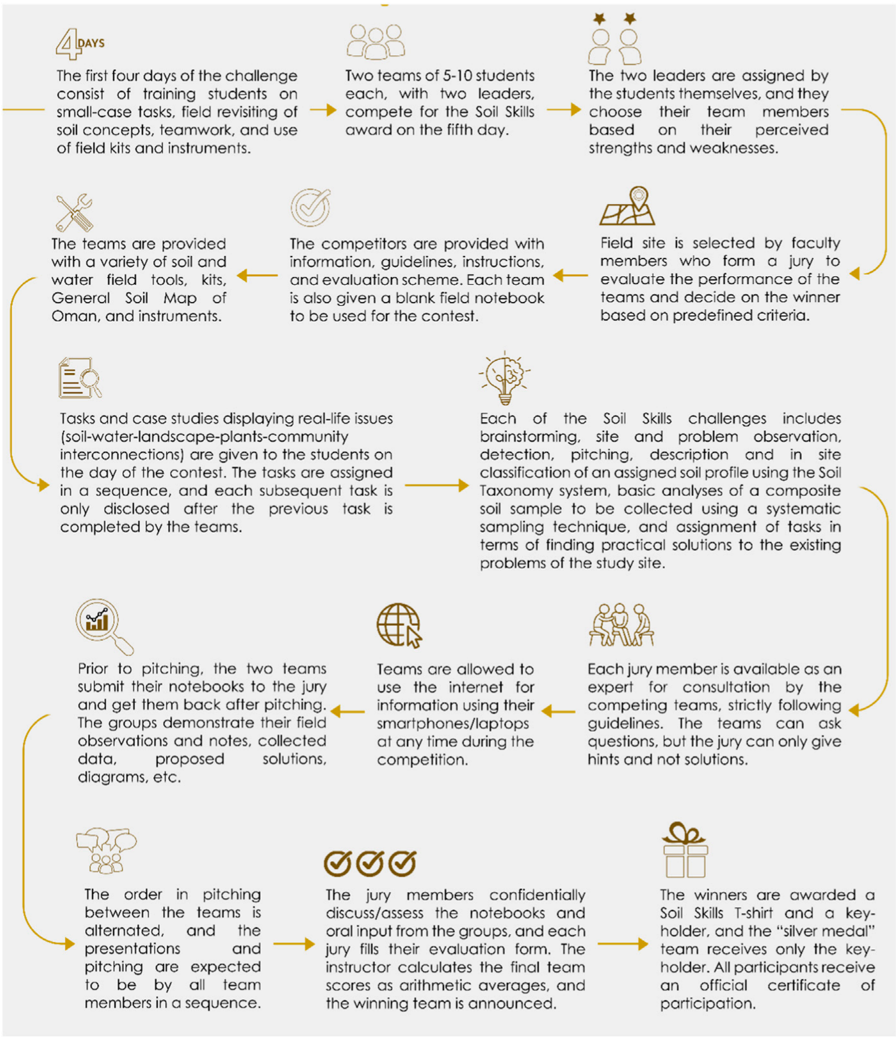

FIGURE 1 | Diagram, which illustrates the procedures and rules adopted in SSK during the four consecutive days of the yearly contest carried out during the January Winter Tour course, offered in 2017–2023.

Conducting a hypothetical crime scene investigation through soil forensics, and v) Installing and programming sensor-based irrigation systems.

These tasks are sequenced, with the revelation of each subsequent task contingent upon the completion of the preceding one. The timing for executing each task is meticulously managed and rigorously kept, with rubrics applied to assess the students' skills in each task (see Al-Ismaily et al., 2021; Al-Maktoumi et al., 2016 for detailed examples of tasks and the rubics used).

Generally, the SSK challenges encapsulate brainstorming, onsite observations, issue and challenges identification, and in-depth analysis (Al-Maktoumi et al., 2016; Al-Ismaily et al., 2019). Sometimes the problems, which the teams confront, are puzzling, i.e., complex, argumentative, and have multiple solutions (Cantor et al., 2015). The aim is to discern practical remedies to the study site's existing predicaments.

Each Jury member serves as a consultant, adhering to strict guidelines. The Juries can offer hints and respond to yes-or-no questions, but must refrain from providing outright solutions. All interactions between teams and experts are kept "isolated", ensuring no exchange of information between the rival teams. Consultation limits are set at 3 min per task, and each team can engage an expert only once for every task.

Teams can consult the Internet using their own electronic mobile devices. However, the imposed time constraints compelled the judicious use of this resource. Post-task completion, teams have to submit and later retrieve their notebooks. Written-drawn sketches depict teams' observations, data, proposed solutions, etc. Importantly, teams cannot access each other's submitted field book, safeguarding originality during oral sessions in front of the Jury. Consistency between written and spoken content is imperative. **Figures 2F, G** vividly depict the essence of teamwork in addressing two pivotal challenges within

FIGURE 2 | Illustration of the SSK activities. **(A)** Soil profile description, sampling and field analysis of collected soil samples. **(B)** Measurement of moisture content across soil profile using ThetaProbe. **(C)** Surface soil sampling. **(D)** Use of hydraulic auger for soil sampling. **(E)** Field method for fast, easy, and cheap measurement of soil infiltration rate. **(F)** Measurement of falaj water flow. **(G)** Installation and programming of irrigation system controller challenge. **(H)** Award ceremony for winning team members. **(I)** Example awards to honor the winning and participated students. **(J)** Group photograph of participating students, Jury, and organizing faculty at the SSK- 2023.

SSK: measuring the water flow of a Falaj and racing against the clock to install and program irrigation system controllers, respectively.

The order of presentations alternates between the teams, with the Jury emphasizing collaborative participation from all team members.

Post-presentation, the Jury confidentially appraises the contents of the field books and verbal contributions. Each Jury member uses an evaluation form to document their assessment. Subsequently, these are consolidated by the lead instructor to derive the final scores, a process spanning approximately 15 min. During this interlude, students could unwind.

At the end of the challenge, the winning team is announced and honored with T-shirts or notebooks with handmade SSK insignia/symbols (**Figures 2H, I**). The runners-up receive key holders or mugs engraved with SSK (**Figure 2H**). All participants are awarded official SSK certificates recognizing their participation. **Figure 2J** depicts a group photograph featuring the participating students, jurors, and the organizing team of the SSK 2023 contest.

It's noteworthy that, akin to the structure in Mikhailova et al. (2015), the SSK tasks were meticulously organized. Unlike Mikhailova et al. (2015), where students had an entire semester to learn and execute their tasks, in our case SSK evaluations are conducted instantaneously in the field.

Evaluation of the SSK Initiative

Adhering to Biggs (1996) constructive alignment theory, our assessment strategy was designed to mirror the pedagogical approach implemented. Evaluations of the SSK initiative's outcome-based learning objectives were conducted through in-field assessments of learning traits, encompassing critical reasoning, proficiency in techniques and equipment, predictive abilities, cause-identification, structured argumentation, proposal of solutions with their justifications, and innovative thinking, among others.

The teams' success in fulfilling their set tasks was similarly assessed [refer to Al-Ismaily et al. (2021) for a detailed rubric elucidating the criteria the juries employed to gauge student performance]. Post-field activities, participants were prompted to engage in a confidential online survey (Al-Ismaily et al., 2021). This feedback was collated and interpreted by the course facilitator. The principal instructor was also furnished with data from the official SQU Course and Teaching Evaluation (Al-Maktoumi et al., 2016). Additionally, a peer assessment exercise was facilitated through email. This assessment, rooted in reciprocity and confidentiality, involved team members assessing their leaders, while the leaders reviewed and provided feedback on the performance of individual team members.

In spring 2018, the introduction of the SSK program to the SWWT course marked a significant improvement in its teaching evaluation scores. The course received a high rating of 3.93 out of 4.0, notably higher than the College's average score of 3.16. This was a substantial increase compared to the course's previous rating pre-SSK of 3.06 out of 4.0 in spring 2017, where the College average was 3.30 at the time. These statistics highlight the positive impact of the SSK program on the course's quality and effectiveness in teaching (Al-Ismaily et al., 2021).

Our questionnaire-based survey, involving 22 students who register the course, highlighted the positive impact of SSK on their transferable skills, encompassing teamwork, communication, problem-solving, creative thinking, observation, and leadership (Al-Ismaily et al., 2021). More than 87% noted an enhanced understanding of soil-water interaction and a greater willingness to express opinions. Every participant in the questionnaire study agreed that "Soil Skills" stimulated new ideas and integrated knowledge across Soil Science courses. The majority (86.4%) expressed satisfaction with SSK activities, such as brainstorming and engaging in scientific debates, finding them both interesting and challenging. Over 95% of students affirmed that the assigned case studies were clear, well-organized, relevant to the Soil Science program, and had adequately allocated time.

Benefits and Strengths of the SSK

The SSK approach offers several benefits and strengths. In practical relevance SSK emphasizes daunting actions involving field-based experiences, the approach enhances students' ability to apply soil science concepts to practical scenarios. This prepares the participants for thriving careers in the fields of soil science, environmental management, agriculture, and related fields. The SSK facilitates deep learning and critical thinking. The SSK encourages students to engage critically with soil science concepts, analyze holistic-complex problems, and develop innovative solutions. It cultivates critical thinking skills necessary for tackling soil-related challenges.

The SSK develops students' collaboration and communication skills. Through group work and teamwork, the SSK approach enhances students' collaboration and communication skills. They learn to effectively communicate ideas, share responsibilities, and work together to achieve common goals.

The SSK enhances students' field skills. Field-based activities incorporate handling field tools and the use of modern instruments, observation and inspection, soil sampling, mapping, and data collection. These skills are valuable for conducting accurate assessments, research, and environmental monitoring.

Limitations and Challenges of Implementing the SSK

Despite its strengths, the SSK approach also has limitations and challenges.

Resource-intensive nature of SSK requires field equipment/kits, laboratory facilities, and transportation for field trips. This may pose challenges in terms of resource availability, funding, and logistics.

The SSK requires careful planning and coordination to integrate field trips, practical exercises, and collaborative activities into the curriculum. This may necessitate fine adjustments to schedules and additional time commitments.

Weather conditions and safety concerns in SSK may levee certain impediments. That may restrict or complicate field trips, affecting the implementation of the approach.

The SSK may need adaptation to suit different educational settings, disciplines, and cultural contexts. It requires consideration of local soil characteristics, regional challenges, and available resources.

Student motivation and engagement in SSK by some students may require additional support from the faculty to adapt to the hectic and deeply interpersonal experience, which depends on specific personality traits.

THE SOIL JUDGING CONTEST (SJC)

Description of the SJC

The state Future Farmers of America, the North American Colleges and Teachers of Agriculture through the Soil Science Society of America and the American Society of Agronomy since 1961 organized soil judging contests for high-school and bachelor-level students (Cooper and Dolan, 2003; Cavinder et al., 2011). The undergraduate contests are carried out, scaffolding from a state in the United States to seven country's regions and, eventually, to a national level (Rees and Johnson, 2020).

Each school develops its own contest but follows the national guidelines. The duration of the contests varies from 1 day to a week. In some cases, soil samples (to be evaluated by students' teams) are mailed to each participating school. From each regional contest, a specified number of top-performing teams advance to the National Collegiate Soils Contest (NCSC). Students progressing to the national contest already have a diversity of experiences in soil profile-cores judging, gained in the contests of the lower level. The NCSC is held during the spring of each year. Host universities are rotated. Some specific elements of the competition are changed each year, to be in congruity with local soils and landscapes at the host university.

The judging tournament, which involves thousands of students being trained in soil morphology and pedology, has been a success (Hill et al., 1984; Cooper and Dolan, 2003). The objectives of an SJC, as defined by Post et al. (1974), are to:

(i) acquire knowledge about soil in a specific landscape with "in-field" training;
(ii) exchange ideas between the students and faculty;
(iii) to advocate soil science as a subject and future profession;
(iv) put on a student's resume the fact of participation in such an academic competition; and
(v) have fun. Post et al. (1974) suggested that the winning aspect should be de-emphasized.

The SJC accents on soil morphology as the best tool to assess soil limitations for various land uses (Vepraskas et al., 1988). of the participating students are typically majoring in soil science, agronomy, forestry, horticulture, education, economics, animal science, geology, geography, natural resources, geotechnical engineering, and environmental studies. Soil judging has been extensively used by many countries since 2012 including Australia and New Zealand (Levin and Morgan, 2013), Brazil (Pedron et al., 2023), Libya (Zurqani et al., 2023), and Taiwan (Chen et al., 2022), among others.

Participation in SJC and the Process Involved

The SJC process typically involves the following steps [see details in Galbraith and Thompson. (2014)].

Contest registration: Students form teams and register for soil judging contests at regional or national levels. These contests are often organized by educational institutions, soil science societies, or agricultural agencies.

Site selection: Contest organizers identify suitable soil pits where participants can observe and evaluate soil profiles. These pits are carefully prepared to represent different soil types and horizons.

Soil profile examination: Teams visit the designated soil pits and examine the exposed soil profiles. Students observe soil properties such as color, texture, structure, consistency, and the presence of horizons.

Data collection and analysis: Teams collect data by measuring soil properties, conducting field tests, and making detailed observations. Students record their detailed findings, paying close attention to distinctive features, soil layering, and any variations within the pit.

Soil classification and interpretation: Based on students' observations and knowledge of soil science principles, teams classify the soil profile according to established soil classification systems. The teams interpret the soil's suitability for various land uses, considering factors such as drainage, fertility, and erosion potential.

Judging and feedback: Teams present their findings and interpretations to a panel of judges. The students explain their reasoning, provide supporting evidence, and respond to questions from the judges. The judges evaluate the teams' performance based on their accuracy, depth of analysis, communication skills, and teamwork.

Emphasis on Critical Thinking, Problem-Solving, and Teamwork Skills

The SJC places a strong emphasis on developing critical thinking, problem-solving, and teamwork skills. Through the process of SJC, students engage in the following activities:

Analysis and interpretation: Students analyze complex soil profiles and apply their knowledge of soil science principles and soil morphology and taxonomy concepts to describe soil layers, identify diagnostic horizons, taxonomically classify soils, and interpret their characteristics and land use implications. One of the primary goals of SJC is to empower students to apply their understanding of soil genesis and classification. This facilitates a deeper comprehension of the interconnected influences of climate, parent material, relief, and organisms on soil formation over time, as well as the ensuing processes. Students are required to make informed decisions and judgments based on their observations and interpretation of soil horizons. The participants critically evaluate the information at hand, consider different possibilities, and justify their decisions with logical reasoning.

The SJC fosters collaboration and teamwork. Students work together in teams, sharing their observations, discussing different perspectives, and arriving at a consensus regarding horizons pedogenic features and diagnostic epi-endo-pedons and ultimately soil classification and interpretation. This collaborative process enhances their ability to work effectively in a team setting.

Students develop their communication skills by presenting their findings and interpretations to judges. The students should articulate their thoughts clearly, provide supporting evidence for their conclusions, respond to questions from the judges, and give coherent feedback. Effective communication is crucial for conveying scientific concepts accurately and convincingly.

Benefits and Strengths of the SJC

SJC offers several benefits and strengths, including:

1. Practical application of soil science: SJC provides "hands-on" practical experience linked specifically to the understanding of how soil morphology and classification together can provide knowledge for land use interpretation. Soil morphology exploration and description of excavated soil pedons is the best tool to assess soil limitations and land use suitability and capabilities (Vepraskas et al., 1988).
2. Development of critical thinking skills: SJC fosters critical thinking by challenging students to analyze complex soil profiles, consider multiple soil formation factors, and make informed judgments based on soil pedogenic processes (Galbraith, 2012). It promotes the ability to think critically, evaluate evidence, and apply scientific principles to solve problems.
3. Teamwork and collaboration: Participating in soil judging contests cultivates teamwork and collaboration skills. Students learn to work effectively in teams, share responsibilities, and collaborate to arrive at a consensus. These skills are transferable to various professional settings that require collaborative problem-solving.
4. Effective communication: The approach emphasizes effective communication as students present their findings, interpretations, and reasoning to judges. This enhances their ability to convey scientific concepts clearly and concisely, strengthening their communication skills.

A survey conducted by Cavinder et al. (2011) found that participation on a judging team increased interpersonal skills including communication, critical thinking, and information management, and that these skills provided an advantage in job placement and success in the chosen profession. However, motivation or activity alone is not as effective for producing student engagement as is the product (not summation) of the two (Barkley and Major, 2020). Through pre- and post-contest surveys completed by 83 and 62 participants respectively, Rees and Johnson. (2020) reported that a significant improvement was observed in five out of seven soil-judging skills. Most students held positive views on soil science after the contest. Feedback highlighted the value of location-based learning, though some criticized environmental factors and long days. Overall, the event was deemed highly educational and beneficial.

Limitations and Challenges of Implementing SJC

While SJC offers numerous benefits, there are some limitations and challenges to consider, including:

Accessibility and resources: Participation in the SJC may require access to suitable soil pits, transportation to contest sites, and availability of necessary equipment and facilities. These factors can pose challenges, particularly for institutions with limited resources or in geographically remote areas.

Time commitment: Preparing for SJC requires a significant amount of time from both students and instructors. It involves organizing practice sessions, field trips, and coordinating team activities. Balancing these demands with other academic responsibilities can be stressful.

Subjectivity of judging: Evaluating SJC participant's performance involves subjective judgments by a panel of judges. While efforts are made to standardize the evaluation process, there may still be some variation in assessments, which can affect the fairness of the competition.

Limited transferability: SJC is specific to soil science education and may not be applicable to other disciplines. Its focus on soil classification and interpretation may not align with the learning objectives of educational contexts, which are only coterminous to classical soil sciences (pedology), for example, soil mechanics.

Student engagement: Not all students may be equally motivated or interested in participating in the SJC. Some students may thrive in competitive environments, while others prefer alternative learning methods. Engaging all students and maintaining their enthusiasm can be a challenge.

CROSS COMPARISON BETWEEN THE SSK AND SJC

In this Section, we address the commonality and difference between two pedagogical methods, SSK and SJC. The aim is to cross-fertilize the two for their mutual advances.

Similarities in Providing Practical, Hands-on Experience in Soil Science

Both SSK and SJC contests overlap in the following characteristics:

- emphasize practical, hands-on experiences in soil science education. They recognize the importance of engaging BSc students in activities that involve soil classification, interpretation, and problem-solving.
- involve field-based learning experiences where students have the opportunity to observe and interact with soil profiles, collect soil samples, and apply soil science principles in a practical context. Field lessons are one of the most effective techniques for teaching soil science (Kasimov et al., 2013; Hartemink et al., 2014; Al-Maktoumi et al., 2016; Smith et al., 2020). In the human psyche, there should be a desire for "soil care," the participation of the body should be provided by experiences ("learning by doing") and spiritual connections to soils create emotional links to them. All three aspects can be perfectly fulfilled with field lessons (Urbańska and Charzyński, 2021).

- aim to bridge the gap between theoretical knowledge and practical application by providing students with direct experiences in soil-related activities, such as soil mapping, sampling, data collection, and analysis.
- focus on developing specific skills and competencies related to soil science, such as soil characterization, analysis, and interpretation; foster deep learning, critical thinking, collaboration, and field skills development. Critical thinking, problem-solving, teamwork, and effective communication skills are common attributes.
- blend egalitarian collaboration (within students' groups) and hierarchical judgment by "elite experts" of the Jury/contest panel are logistically and financially supported by higher education institutions and professional societies.
- students participating in SSK and SJC are surveyed by the organizers.

Differences Between SSK and SJC

The SSK and SJC contests are different in some methodological aspects, learning outcomes, and technicalities.

1. Methodology: The SSK, as a child of "Wetskills" utilizes problem-based learning, active learning, and engagement of students in activities through classroom instructions, laboratory exercises, field trips, and inquiry-based learning to facilitate the acquisition of strong skills and knowledge in disciplines broader than "soil science" *per se*. SJC is more specific in targeting soil pedons, profiles, cores, and taxa.
2. Learning Outcomes: the SSK aims to inculcate a broader understanding of soil science concepts in companion with other disciplines including the ability to solve subtle soil-water-land-geoengineering-related problems. However, the understanding in the SJC is deeper but narrower: Students work collaboratively in teams to assess soil profiles and classify soils, less trespassing to the "sister disciplines" in sciences and engineering. At SQU students learn once by participating in SS, while in the United States some students participate in SJC for several academic years.
3. The SSK contest is managed and budgeted by one academic department at a higher education institution in one country (Oman), benefiting from an international (Dutch) program of "Wetskills." The pool of organizers-experts in SJC is geographically broader and resources of participating universities and national agencies (USDA-NRCS) are ubiquitous. SJC surveys sample participating students from different locales in the United States.
4. Historically, SJC has a much longer horizon of post-auditing and planning, as compared with the SSK. This is both a strength and a weakness. Specifically, it is easier to tailor an educational contest of a specific academic program to meet its changing needs or adapt it quickly on demand, as opposed to managing a much larger contest such as the SJC. Coordination and innovations within SWAE in the SSK are overall easier to implement than in the SJC with multilevel governance.
5. The SJC is already implemented in the online (e-contest) mode (Owen et al., 2021), while to date, the SSK is not.

Suitability for Different Educational Settings and Student Preferences

SSK is suitable for educational settings that emphasize overarching and holistic knowledge and skills development in soil science. It is well-suited for students interested in pursuing careers in soil science and related fields. Both SJC and SSK are suitable for educational settings that value competitive environments, teamwork, and the development of critical thinking and problem-solving skills. It appeals to students who thrive in settings analogous to team sports (e.g., baseball, basketball, football), and enjoy collaborating with a "gold medal" climax, enjoying the challenge of contests *per se*, and prefer a more structured and competitive learning experience.

Considerations for Educators in Choosing the Right Approach

When choosing between the SSK and the SJC or their combinations, educators may consider the following factors:

1. Learning Objectives. The SSK approach may be more suitable if the emphasis is on multi-intra-disciplinary knowledge acquisition, practical skills development, and a deep understanding of soil science concepts. The SJC may be preferable if the focus is on developing critical thinking, problem-solving, teamwork, and communication skills within a competitive context.
2. Educational Context: Educators should consider the resources, facilities, and logistical constraints of their institutions. The SSK requires field equipment, laboratory facilities, and transportation for field trips. The SJC may require access to suitable soil pits/core samples, coordination of judging contests, and collaboration with other educational/professional institutions. Educators should assess the feasibility and availability of resources before choosing the most suitable approach, or their combinations.
3. Student Preferences and Engagement: Educators should consider student preferences and engagement when selecting the approach. Some students may prefer hands-on activities and field experiences offered by the SSK. Others may thrive in competitive environments and enjoy the teamwork and challenges of soil judging contests provided by the SJC. Educators should assess the interests, learning styles, and differences of their students, e.g., cultural, gender, and physical strengths to ensure maximum engagement and motivation.
4. Learning Outcomes: Educators should align the chosen approach with desired learning outcomes. If the goal is to develop specific field skills, a deep understanding of soil science concepts, and practical application, the SJC approach may be more appropriate. If the focus is on developing critical thinking, problem-solving, teamwork,

and communication skills within a competitive context, the SSK may be a better fit.

CONCLUDING REMARKS AND PERSPECTIVES

Educators should provide students with the opportunity and time to develop their own thinking, creativity, and action; only the combination of such attributes with appropriate soil science content in textbooks, supported by field lessons, can shape a "new" citizen who is ready to tackle the future challenges facing our planet. From this perspective, the concept of "from idea to action" (Xylander and Zumkowski-Xylander, 2018) should be propelled worldwide. Some educational solutions will help to achieve this goal. For instance, theoretical issues in the field of knowledge of facts (e.g., soil profile, soil genesis, country, and world soils, etc.) should be discussed in connection with the reality.

University teachers should carefully consider their specific context, learning goals, available resources, and student preferences when choosing the most suitable approach. By aligning the chosen approach with the desired outcomes, educators can foster knowledge acquisition, critical thinking, problem-solving, teamwork, and effective communication skills among students.

The following peculiarities distinguish the mode of the SSK-SJC soil contests:

a) The SSK, as compared with other BSc students' tournaments, is not narrowly focused on soil profile description (either American taxonomy or any other national classification of soils based on their genesis). The SSK gives a broader, more multidisciplinary pedagogical perspective and prospective.
b) In the SSK, students have to analyze and propose technical (e.g., engineering, environmental, social-cultural, and regulatory) solutions to daunting problems, that students are confronting in the field, e.g., the consequences of secondary salinization of agricultural land, waterlogging of foundations of buildings constructed on soils with subjacent perched aquifers, illegal disposal of municipal waste in wadi (arroyo) channels, and their banks, siltation of reservoirs of local dams, peculiarities of urban soils, the impact of devastating flashfloods on deluded urban districts and villages with the necessity to propose agroforestry and geotechnical methods to mitigate such floods, etc.
c) Different techniques and instruments have to be used by students. They have to quickly learn these tools and means in the field conditions, e.g., assembling (in 30 min) an irrigation unit with a controller, soil moisture sensors, data logger, or soil fertility evaluation using soil kits and pH-EC meters, measuring the flow rates by a current meter in farmers' falaj.[4]
d) SSK students are challenged to come up with an express method of assessing the parameters of soil and water systems when advanced instruments are instructed not to be used. The students had to improvise. For example, in one of the contests, the students are given a shovel, ruler, stopwatch, and container with a limited quantity of water. The task is to contrive an *ad hoc* protocol to evaluate the infiltration rate, without a double-ring or tension infiltrometer. The teams of students, upon intensive but short discussions, arrive at several ideas, e.g., the construction of a mini-basin with a shoveled bed and confining bunds, which allows for measuring the infiltration rate (see **Figure 2E**).
e) Each new academic year, several tasks in SSK are updated. For example, in the most recent contest of 2022, the students acted as forensic detectives (the Konan Doyle-type "soil Sherlock Holmes"). They had to decipher the soil-buried footprints of a hypothetical crime, committed at a remote site in Muscat. The new cohorts of students enjoy these overhauled tasks.
f) During the SSK, the soil science majoring students, who have a stronger background, as compared with other participating students with other majors, are *au fait* in the foundations of soil sciences, i.e., they teach their water technology classmates several fields/instrumentation techniques, e.g., soil profile description, basic of soil genesis and classification, and soil fertility assessments. Vice versa, the water technology students, who are more versed in hydraulics, fluid mechanics, and calculus, help to upgrade the level of soil science students in these disciplines.

We anticipate that the intertwining of the SSK with the SJC may have the following implications-extension:

1) Establishment of an in-depth, problem-based, practical enjoyable, and competitive learning experience, which closely aligns with professional scenarios requiring multi-, intra-disciplinary mindsets. It will facilitate students' application of soil science knowledge to emerging quandaries. Students' abilities and self-efficacy in bridging their acquired academic baggage (obtained in classrooms' lectures, textbooks, and laboratories) will be combined and upgraded with the soft and dexterity skills;
2) Students' mindset with metacognitive inquiry-based learning attributes such as a better capacity to gather information and knowledge, and the ability to collaboratively use this to formulate logical solutions will be enhanced;
3) The vital significance of soil sciences in relation to other academic disciplines and the broader public will be fostered. The SJC and the SSK, combined with their propelling at local, national, and international levels, if bolstered by robust media coverage, will hold the potential to thrust soil science back into the limelight, rekindling its visibility and relevance across scientific disciplines and the public at large;
4) The SSK and the SJC-exposed students will recognize the contextual nature of problems, and the need to work and

[4]https://en.wikipedia.org/wiki/Aflaj_Irrigation_Systems_of_Oman

communicate with the broader multi-cross-disciplinary community of experts and "citizen scientists";

and

5) The "back-to-field-work" principle is reinstated. Both the SJC and the SSK prioritize hands-on fieldwork in their pedagogical approaches. This will undoubtedly serve as a catalyst, motivating researchers and students to recognize and embrace the immense value of field studies.

Ahead are some areas that warrant further investigation:

1. Comparative Studies: Conducting comparative studies to assess the effectiveness of the SSK and the SJC in different educational settings and student populations would provide valuable insights.
2. Assessment Methods: Developing robust assessment methods that align with the learning outcomes of the SSK and SJC is essential. These assessments should go beyond traditional exams and consider authentic tasks and scenarios.
3. Integration with Technology: Researchers can investigate the use of digital tools, virtual field trips, online simulations, and data analysis software to augment student learning experiences in the field. Technology can provide the SSK and the SJC with opportunities for remote teaching and learning, data visualization, and interactive platforms, expanding access to soil science data and information beyond the limitations of physical resources at a specific geographical locale.
4. Teacher Training and Professional Development: Providing adequate training and professional development opportunities for educators is crucial for the effective implementation of the SSK and the SJC. The design of the SSK-SJC training programs will equip educators with the knowledge, skills, and instructional strategies necessary to implement these approaches effectively.
5. Inclusivity and Diversity: the SSK and the SJC approaches should be accessible and engaging for students from diverse backgrounds, including underrepresented groups and students with different learning styles. Investigating strategies to address potential barriers and biases in soil science education can contribute to creating an inclusive and equitable learning environment for all students.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

All photographs in the manuscript were taken by the lead author, SA-I. The majority of the identifiable images feature BSc students from SQU who were enrolled in the SWWT course. Prior to taking these photographs, all students were informed of their intended use and gave their consent on exposing these photos. Any remaining identifiable individuals in the photographs are co-authors of this manuscript and have also given their consent for publication.

AUTHOR CONTRIBUTIONS

SA-I and AK: A substantial contribution to the concept or design of the manuscript; AhA-M: Revised the manuscript critically for important intellectual content; HA-B, DB, AA-S, and AlA-M: Revised the manuscript for critical feedback. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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