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Education to address emerging needs in animal genomics

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Introduction

The rapid advance of genomics—spanning high-throughput sequencing, bioinformatics, and genome-to-phenome analytics—has transformed animal science research and practice. Land-Grant Universities have a historic mission to democratize practical science education and research, which positions them to translate genomics advances into curricula and workforce preparation (National Education Association, 2022). In parallel, national research and workforce development programs emphasize the need for cross-disciplinary training, experiential learning, and equitable access to advanced technologies to ensure a competitive agricultural workforce (Rexroad et al., 2019; USDA National Institute of Food and Agriculture, 2025).

Despite growing research capacity, integration of contemporary genomics into undergraduate and graduate instruction remains uneven, particularly for whole-genome sequencing, pangenomics, and ethical, legal, and social implications (ELSI). Prior studies indicate that genomics education increases student engagement and confidence while highlighting the need for aligned data-science competencies (Whitley et al., 2020; Koltes et al., 2019). To inform targeted improvements, we conducted a nationwide survey to identify strengths, gaps, and priorities in animal genomics education across U.S. Land-Grant Universities.

Materials & Methods

We conducted a cross-sectional survey using the Qualtrics platform to assess current practices and emerging needs in animal genomics education. The North Carolina A&T State University Institutional Review Board reviewed and approved the protocol to ensure ethical conduct in research involving human participants. Participation was voluntary, and no personally identifying information was collected to preserve respondent confidentiality.

Invitations were distributed via professional networks, academic listservs, and direct outreach to animal science departments in Land-Grant Universities. Inclusion criteria required that respondents be engaged in animal genomics teaching, research, extension, or collaborative activities. A total of 44 professionals completed the survey, representing all four U.S. census regions; several international collaborators also participated, providing external perspectives on U.S.-based educational practices.

The survey instrument included closed-ended items and free-text prompts organized into four domains: course availability and scope; faculty familiarity with applied genomics techniques (e.g., genetic markers, genomic prediction, bioinformatics) and advanced topics (e.g., whole-genome sequencing, pangenomics, ELSI); perceived importance of genomics for student preparedness and workforce outcomes; and barriers and prioritization relative to other emerging technologies. Key items recorded departmental course presence (yes/no) and agreement with statements using categorical response options that enabled reporting of percentages.

Responses were summarized using descriptive statistics to report the proportion of respondents endorsing each option. Percentages reflect the share of the 44 respondents selecting each response category. Inferential analyses were not conducted, as the goal was landscape assessment and needs identification (Nisselle et al., 2024; Johnson et al., 2022).

Results

A total of 44 professionals engaged in animal genomics research, teaching, or collaborative work completed the survey. Respondents represented all four U.S. geographic regions, with additional participation from international collaborators.

More than half of respondents (55%) indicated that their departments offer genomics or genomics-related coursework. These courses commonly cover foundational genetics, quantitative genomics, molecular tools used in breeding, and introductory bioinformatics. Several departments integrate genome-wide association studies, genomic prediction, and functional annotation into advanced undergraduate or graduate instruction (Green et al., 2007; Koltes et al., 2019).

Respondents reported strong familiarity with applied and core genomics tools, including genome sequencing technologies (90.4% at least moderately familiar), bioinformatics (82.7%), and genomic applications in animal breeding (82.7%). Familiarity was lower for advanced or integrative areas such as pangenomics (73.1%), ethical, legal, and social issues (75.0%), and funding-related genomics knowledge (65.4%). Only 11% agreed that genomics currently receives sufficient emphasis in departmental curricula, and 9% agreed that faculty possess strong instructional expertise in genomics (Chen and Kim, 2014; Nisselle et al., 2024).

A majority of respondents endorsed the importance of genomics to agricultural innovation and student preparation. Specifically, 61% agreed that genomics has significant agricultural applications, 36% indicated contributions to long-term sustainability, 62% affirmed that genomics education is critical to animal science, 51% reported enhanced student career opportunities, and 55% stated that students should graduate with a strong foundational understanding of genomics (Rexroad et al., 2019; USDA National Institute of Food and Agriculture, 2025).

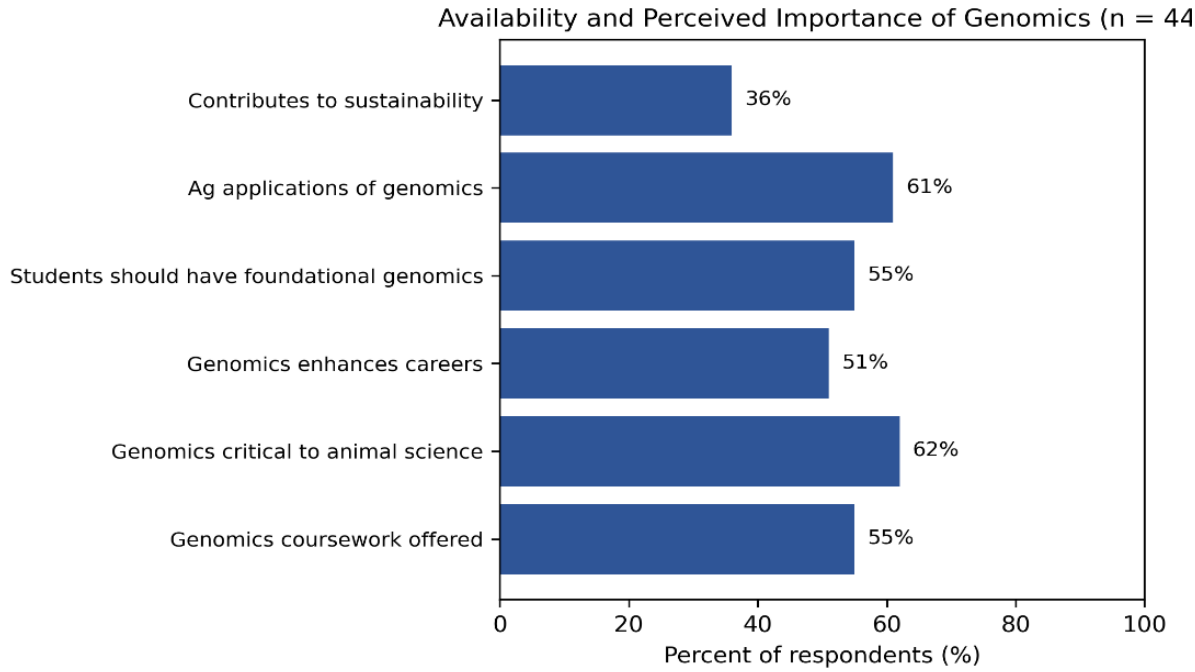

Figure 1. Availability of genomics coursework and perceived importance of genomics education indicators reported by survey respondents (n = 44)

Despite broad support, capacity challenges persist. Only one in nine respondents perceived sufficient curriculum emphasis on genomics, and fewer than one in ten perceived adequate faculty instructional expertise. Ethical concerns were not widely viewed as barriers (13%), but

25% indicated that genomics should be prioritized over other emerging technologies to meet workforce demands (Roberts et al., 2025; Chen and Kim, 2014).

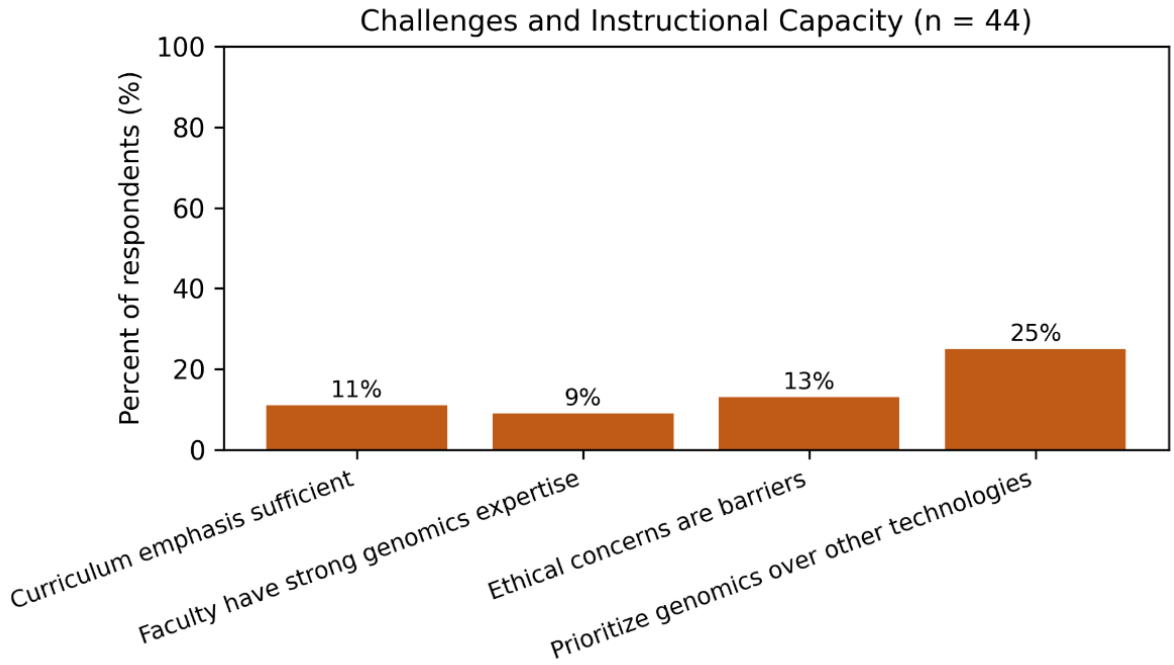

Figure 2. Reported challenges and instructional capacity indicators for genomics education among survey respondents (n = 44).

Discussion

This multi-institution snapshot indicates that foundational genomics instruction is increasingly present in animal science programs, while depth in advanced techniques and instructional capacity remains uneven. These findings parallel results from scoping reviews documenting variability in genomics education needs assessments and limited evaluation of downstream outcomes (Nisselle et al., 2024). International workforce assessments similarly highlight the need for substantial modification of training approaches and expanded topic coverage (Johnson et al., 2022).

Evidence from public-health genomics education suggests that professional development, continuing education, web-based training, and conference-based learning can effectively address instructional gaps (Chen and Kim, 2014). In animal agriculture, the USDA Genome to Phenome roadmap underscores the strategic importance of integrating genomics to improve productivity, resilience, and sustainability (Green et al., 2007; Rexroad et al., 2019). Alignment with national workforce initiatives and capacity-building programs can further support equitable workforce preparation (USDA National Institute of Food and Agriculture, 2025).

Prospective evaluation is essential to ensure accountability and impact. Recent guidance emphasizes the use of common data elements to track resources, scientific output, collaboration, and workforce outcomes, enabling continuous improvement (Roberts et al., 2025).

Conclusions

Our survey demonstrates strong consensus that genomics is central to animal science education and workforce readiness, alongside unmet needs in advanced content and instructional capacity. We recommend systematic needs assessments, modular data-driven learning experiences, integration of ELSI across curricula, coordinated faculty development and

resource sharing, and prospective evaluation using common data elements to track short- and long-term outcomes.

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